RAILWAY MECHANICAL ENGINEERING

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RAILWAY
MECHANICAL ENGINEERING

RAILWAY MECHANICAL ENGINEERING

A PRACTICAL TREATISE BY ENGINEERING EXPERTS

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VOLUME I

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PUBLISHERS' NOTE

Great advances have been made in recent years in almost every branch of railway mechanical engineering. The improvements in the design and construction of the locomotive itself have been stimulated by the increasing congestion of traffic. Expensive track quadruplication can sometimes be postponed by running heavier trains at higher speeds, or even the same speeds as at present. The high cost of fuel, the increasing power of the locomotive, and the competition of electricity as a tractive power have forced steam locomotive designers to secure thermal economy with increasing power, as far as may be. Progress has therefore been in the direction of heavier, more powerful, faster, and more economical engines. These improvements have been attained by the use of:

1. Larger boilers, fitted with superheaters, and feed-water heaters.
2. Improved design of firebox.
3. Lighter moving parts, made of stronger materials, such as nickel steel.
5. Lighter and more accessible valve-gear.

Development has been even more rapid in the field of electric traction. The superiority of the multiple-unit electric train over the steam train for handling heavy suburban traffic has long been recognized by railway authorities, but the application of electric traction to main-line haulage is a comparatively recent growth. The first installation in Great Britain, on a reasonably extensive scale, was the Newport-Shildon Electrification on the North-Eastern Railway. Here coal trains are hauled by electric locomotives which handle 1500-ton trains efficiently and economically. The application of electric locomotives to main-line work is an alternative way of solving the same traffic problem, viz. the necessity of finding a means of economically hauling much heavier trains at higher speeds, so as to reduce working costs to a minimum, and to avoid the expense of quadruplicating sections of main line on which traffic is congested. The electric locomotive is a much more

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powerful hauling machine than the steam locomotive. It is easy to see why this is so, if we remember that the complete power outfit is housed on the steam locomotive, viz. coal, furnace, boiler, engine, water, &c., whereas only the electric motors and control apparatus are housed on the electric locomotive.

Perhaps the greatest progress in the rolling-stock department has been made in the design of goods wagons of high capacity—another movement to secure a heavier train. As regards passenger-coaches, the most definite improvements have been in the electric lighting of carriages and the increased cleanliness of the compartments.

These developments, as well as the general practice of modern railway mechanical engineering, are described in the ensuing chapters by experts who possess specialized knowledge of the subjects on which they write.

The material of the well-known work *Modern Railway Working*—published by us in 1912—has been placed at the disposal of the contributors in compiling this new work.

December, 1922.

CONTENTS

VOLUME I

TESTS OF MATERIALS USED IN BRITISH LOCOMOTIVE CONSTRUCTION

By the late THOMAS NASH, formerly Director of the Sheffield Testing Works. Revised by WILLIAM CLELAND, B.Sc.

Page

Materials—Steel—Iron—Copper, &c.—Tests Generally Employed —Preparation of Samples for Tensile and Bending Tests —Notes on the Making of Tensile Tests—Elastic Stress —Testing Machines — Chemical Analyses — Investigations of Materials which have been in Use—Specified Tests— Schedule of Tests Recommended - - - - - - 3

MODERN LOCOMOTIVE DESIGN

By A. R. BELL, Mem.Inst.Loco.Eng.

CHAP.

I. THE EVOLUTION OF THE MODERN LOCOMOTIVE. Nature of Traffic —Weight of Trains—High-speed Running—Character of Permanent Way—Gauge Restrictions—Earlier Efforts to meet Modern Requirements—Higher Steam Pressures—Fireboxes —Other Firebox Developments—Long Narrow Fireboxes—Shallow *v.* Deep Fireboxes—Water Tubes—Cylindrical Corrugated Firebox—Steel for Inner Fireboxes—Steel Boiler Tubes —Serve Boiler Tubes—Longer Boiler Tubes—Small Boilers Standard Practice at 1895—The Birth of the Modern British Locomotive Boiler—The Boiler's Growth since 1895—The Long Boiler—Coned or Tapering Boilers—Dispensing with Steam Dome—Use of Superheating—Cost and Efficiency—Other Considerations—Utilization of Energy—Widely differing Practice as to Cylinder and Wheel Dimensions and Arrangement—Compounding—Webb's Compounds and their Fate—Revival of British Interest in Compounding—Smith's Three-cylinder Compound System on the Midland—Smith's Compounds on the North-Eastern and Great Central—Lancashire and Yorkshire Compounds—Dean's Compounds on the Great

CHAP. Page

Western—Churchward's Trials of Compounds—Ivatt's Four-cylinder Compounds—The Prospects of Compounding in Britain—The Express Engine of the Future—Valve Gear - 21

II. MODERN LOCOMOTIVE TYPES. List of Types—Passenger Tender Engines: The "Singles"—The Four-coupled Type—Diversity in Design—Widely varying Ratios—Influence of Local Conditions on Design—A Typical 4-4-0 Line—Great Western "City" and "County" Classes—Four-cylinder Simple Engines—The "Great Bear"—London and South-Western Four-cylinder Simple Engines—The "Atlantic" Type—Limitations of "Atlantics" - - - - - - - - - - 39

III. TANK ENGINES. Tank Engines for Express Work—0-4-4 Type—0-6-0 Type—0-6-2 Type—0-6-4 Type—4-4-4 Type—Earlier 2-6-2 Type—The 2-4-2 Forerunners on the Great Western and Lancashire and Yorkshire—Later 2-6-2 Type—4-4-2 Tanks—2-4-2 Type—4-6-0 Type—0-8-0 and 0-8-2 Types—Great Western "Consolidation" Tanks—0-8-4 and 4-8-0 Banking Tanks—4-6-2 Type—4-6-4 Type - - 52

IV. GOODS ENGINES.—Development of Goods Engines—0-6-0 Type—2-6-0 "Mogul" Type—Great Western "Moguls"—Great Southern and Western "Moguls"—4-6-0 Type—0-8-0 Type—Boilers Common to Various Types—Other 0-8-0 Engines—2-8-0 "Consolidation" Type—Future Design in Goods Engines - - - - - - - - - - 59

V. RAIL MOTOR-CARS. Introductory—"Auto Trains"—Great Western Practice—Rail Car Design - - - - - - - - 65

THE DESIGN AND CONSTRUCTION OF CARRIAGES AND WAGONS

By S. WARNER, Carriage and Wagon Superintendent, London and South-Western Railway

I. INTRODUCTORY AND GENERAL. Rolling Stock and a Reminiscence—Wide Range of Carriage Construction—The Comfort of the Passengers—The Battle of the Brakes—Loading Gauges—Cost of Rolling Stock - - - - - - - - 87

II. TIMBER. Oak—Teak—Pitch Pine—Mahogany—White and Red Fir—Jarrah and Karri—Decorative Woods—Seasoning - - 94

III. UNDERFRAMES. Determining Factors in Underframe Design—Design of Four-wheeled Underframes—Definitions of Frame Members—Six-wheeled Underframe—Short Vehicles for Suburban Trains—Bogie Coach Underframe—Buffing of Close-coupled Vehicles—Shrinkage, &c., in Underframes—Construction of All-steel Underframe—Great Western 70-ft. Underframe - - - - - - - - - - 96

CHAP Page

IV. BOGIES. Wheels on Rails—General Features of Pressed-steel Bogies—Action of Bolsters on Curves, &c.—The Equalizing-bar Bogie—London and North-Western Railway Six-wheeled Bogie—Wide-bolster Bogie—Diamond-frame Bogie - - 106

V. WHEELS AND AXLEBOXES. Mansell Wheel Specification—Security of Tyres on Wood Centres—Wheel Dimensions—Wheel Balancing—The Kitson Wheel—Iron Wheels—Wheel Gauges—Axlebox Design—Axle Oil—Pressure on Journals—North-Western and Great Western Standard Axleboxes—Private Owners' Standard Axleboxes - - - - - - - 119

VI. SPRINGS AND IRONWORK DETAILS. Specification for Laminated Bearing Springs—Specification for Volute and Helical Springs—General Design of Springs: Formulæ—Helical and Volute Springs—Indiarubber Springs—Ironwork Details—Carriage Drawbar Hooks: Screw Couplings—Buffers, Axleguards, and Scroll Irons—Corridor Gangways—Drawbar Release for Slipping Coaches—Wagon Drawbar Hooks, Couplings, and Cradles—Self-contained Buffers—Brake Blocks, &c. - - - 136

VII. BODYMAKING AND TYPE OF BODIES. General Principles of Design—Carriage Joinery—Arrangement of Flooring—Body Framework—Erection—Panelling—Roof Support—56-ft. Corridor Composite Carriage—56-ft. Dining Car—Sleeping Saloon—Family and Invalid Saloons—Milk Vans—Travelling Post Offices - - - - - - - - - - - 152

VIII. FINISHING, TRIMMING, VENTILATING, POLISHING, PAINTING, AND STEAM HEATING. First-class Compartment—Second- and Third-class Compartments—Frameless Windows; Lavatory Fittings—Trimming—Upholstery in First-class Compartment—Second- and Third-class Compartments—Ventilation—Polishing—Economic Aspects of Painting and Varnishing—Painting of Carriage Body—Painting of Carriage Steel Underframe—Painting of Compartment Interiors—Roof Painting—Varnishing of Teak Coaches—Painting of Wagons and Road Vans—Steam Heating—General Arrangement of Fittings - 171

IX. CONTINUOUS AND HAND BRAKES—PASSENGER COMMUNICATION. Description of Vacuum Brake—Action—Combined Brake Cylinder: Ball Valve—Guard's Van Valve and Vacuum Gauge—Passenger Communication Valves; Slip Couplings—"F-class" Cylinder; Rapid-acting Valves—Horizontal Brake Cylinder; High-speed Ball Valve—Piston Stroke and Braking Power—Westinghouse Brake—Action—Ordinary Triple Valve—Quick-acting Triple Valve—Moderate and Rapid Brake Applications—Improved Triple Valve—Action of Improved Triple Valve—Brake Cylinders—Empty and Load Brake—Release Valve: Hose Couplings—Passenger-communication Apparatus—Hand Brakes—Board of Trade Action affecting Brakes—Examples of Either-side Brakes - - - - 187

CHAP. Page

X. WAGONS AND MISCELLANEOUS TYPES OF STOCK. Specifications for Private Owners' Wagons—Specification for 10-ton Wagon —Specification for 15-ton Wagons—Private Owners' 20-ton Wagon—Private Owners' 30-ton Wagon—Tank Wagons—Covered Goods Vans—Cattle Trucks—Board of Agriculture Rules: Special Vehicles—Boiler and Girder Wagons—Timber Wagons—Rail Trucks and Ballast Wagons—Meat-traffic Vans —Standardization of Wagons and Details—Guards' Vans for Goods Trains—Carriage Trucks—Horse Boxes - - - 218

XI. HORSE-DRAWN ROAD VEHICLES. Introductory — Building of Three-horse Vans: Frame and Body—Hind Carriage—Fore Carriage: Brake Work—Wheels—Springs—Ironwork: Wheel-locking Chain—Tilt or Cover: Driver's Dickey: Painting - 245

XII. MECHANICALLY PROPELLED ROAD VEHICLES. Types of Motor Vans—Sets of Vehicles to speed up Transport of Goods—Alternative Methods to facilitate Loading—Electrically propelled Platform Trolley Sets - - - - - - - 253

RAILWAY-CARRIAGE LIGHTING

By SIR HENRY FOWLER, K.B.E., M.Inst.C.E., M.I.Mech.E.

I. CARRIAGE-LIGHTING REQUIREMENTS AND ECONOMICS. Introductory—Rape-oil Lamps—Question of Cost—Gas *versus* Electric Light—Disposition of the Lamps—Importance of Reflecting Surfaces - - - - - - - - - - - - 263

II. GAS LIGHTING. Class of Oil—Arrangement of Retorts—Manufacturing the Gas—Compressing the Gas—Fuel Consumption; By-products—Filling the Coach Cylinders—Coach Cylinders and Connections—The Flat-flame Vertical Burner—Incandescent Gas Lamps - - - - - - - - - 268

III. ELECTRIC LIGHTING. Stone's System—Electrically Controlled Voltage Systems: The "Vickers" Single-battery System—Leitner-Lucas System—Train Lighting: Dalziel's Constant-voltage System - - - - - - - - - - - - 281

LIST OF PLATES

		Facing page
	Express Engines of the Atlantic Type	69
	British Express Locomotives of the 4–4–0 Type	70
	Modern British Express Locomotives	71
	Types of Tank Engines	75
	Modern British Locomotives	80
	Types of Six-coupled Goods Engines	81
	Eight-coupled Goods Engines and Rail Motor-cars	82
	Types of Steam Rail Motor-cars	83
Plate I	Early Types of Railway Carriages—Third-class Brake; Composite Carriage	88
II	Underframe for 21-ft. Horsebox	98
III	Underframe for Special Milk Van	100
IV	London and South-Western Railway 56-ft. Carriage Underframe; Great Western Railway 70-ft. Carriage Underframe	102
V	Invalid Coach	166
VI	Interior of Travelling Post Office (London and North-Western Railway)	170
VII	Travelling Post Office (London and North-Western Railway)	170
VIII	General Arrangement of Westinghouse Brake	200
IX	Three-horse Road Van	246
X	Engine- and Compressor-room in Oil-gas Works	272

FOLDER TABLES

Table X	Pioneer Four-cylinder Simple Engines	46
XIII	Representative British Locomotive of "Atlantic" or 4–4–2 Type	50
XIV	Representative British Locomotives of the 4–6–0 Type	52

TESTS OF MATERIALS USED IN BRITISH LOCOMOTIVE CONSTRUCTION

BY THE LATE

THOMAS NASH

(Formerly Director of the Sheffield Testing Works)

REVISED BY

WILLIAM CLELAND, B.Sc.

Tests of Materials Used in British Locomotive Construction

Materials.—The materials generally used in British locomotive construction are:

Steel.—*Mild steel in the form of plates* for main and bogie frame plates, boiler barrels, outer firebox shells, smokeboxes, boiler tubes, superheater tubes, buffers, buffer beams, side chains, longitudinal boiler stays, *and sometimes inner firebox plates, axles, &c.*

In the form of bars or forgings for connecting and coupling rods, piston rods, valve gear, regulator rods, spring gear and brake gear, buffers, drawgear, rivets, &c.

Special steel forgings for straight and crank axles, crank pins, and slide bars.

Hard steel for tyres and springs.

Steel castings for wheel centres, axleboxes and keys, horn blocks, *motion plates, bogie centres, &c.*

Iron.—*Wrought iron* for boiler barrels, outer firebox shells, smokeboxes, boiler tubes, buffers, drawgear, side chains, longitudinal boiler stays, spring buckles, foundation rings, rivets, and sometimes inner firebox plates, &c.

Swedish charcoal iron for boiler tubes.

Cast iron for cylinders, steam chests, exhaust pipes, bogie and tender axleboxes, &c.

Copper, &c.—*Copper* for inside fireboxes, steam pipes, and occasionally for *boiler tubes.*

Brasses, gun metal, and other alloys used for boiler tubes, the bearings of axleboxes, side rods, piston and valve-rod packings and bearings, &c.

Tests Generally Employed.—The tests applied to these materials consist, in the great majority of cases, of tensile tests supplemented by some rough bending tests, and, in the case of, say, boiler plates, drifting tests, also transverse tests for cast iron, and bulging, flanging, and flattening tests for tubes. In a great majority of cases the tensile tests, when properly made, give a fair indication of the value of the various materials used in locomotive construction, but they are not to be entirely depended upon, as materials sometimes have objectionable properties which ordinary tensile tests do not reveal.

A knowledge of the chemical composition of the materials employed is very desirable, as, in most of the cases of unsatisfactory materials that the writer has met with that have given trouble in practice, the chemical composition has been chiefly responsible.

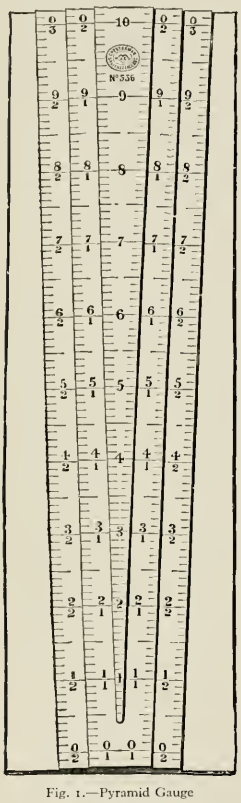


Fig. 1.—Pyramid Gauge

Although not yet much used for materials employed in the construction of locomotives, impact (Izod), "reversals-of-stress", Brinell, and other tests are now adopted for various constructional materials. Some of these tests have revealed properties not revealed by the ordinary tensile tests.

In the case of iron and steel, especially the latter, which is now the material most used in locomotive construction, the value and reliability of various qualities generally vary (as does the market price) in inverse proportion to the amount of sulphur and phosphorus present, given a correct percentage of carbon and careful and intelligent *thermal treatment*.

Preparation of Samples for Tensile and Bending Tests.—It is not generally practicable, where ordinary machining is done, to avoid altogether some tool marks or scratches, but it is very important that such tool marks or scratches, where they exist, should not be at right angles to the length of the specimens. Planing and milling therefore is preferable, say, to slotting. In the case of round samples, such tool marks as exist must, with present appliances, be approximately at right angles to the direction of the tensile stress, and for this reason turned samples should be very carefully finished either by grinding or, in the case of brittle material such as cast iron and very hard steels, draw-filing them. It is very important that the body part of the test piece should be straight, and so prepared at the ends that a bending action does not take place when the tensile stress is applied. This is very important in the case of cast iron, which should be tested in ball-and-socket holders, and prepared as shown on Table 5 on the following sheet of "Forms and Dimensions of Test Specimens and their Preparation".

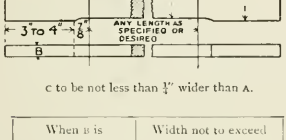
Notes on the Making of Tensile Tests. — To get accurate results from the tensile tests, it is necessary to hold the sample in the testing machine during the test, so that the centre line of the stress

FORMS AND DIMENSIONS OF TEST SPECIMENS AND THEIR PREPARATION

The general forms and dimensions of test specimens adopted by the Sheffield Testing Works, for locomotive materials, are given in the following tables:

TABLE 1

Iron and mild-steel boiler, frame, and general plates, angles, tees, flat bars, and copper plates, &c.

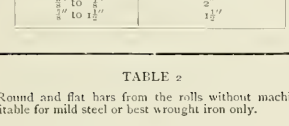


C to be not less than ¼" wider than A.

When B is	Width not to exceed
0 to ⅜"	2½"
⅜" to ⅞"	2"
⅞" to 1½"	1½"

TABLE 2

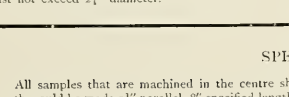
Round and flat bars from the rolls without machining. Suitable for mild steel or best wrought iron only.



Iron or mild-steel rounds from ½" to 2¼" diameter.
Flat iron or mild-steel plates any width from ½" to 4½", and thickness from ⅛" to 1½".
Square bars of iron or mild steel from ½" to 2" square.

TABLE 3

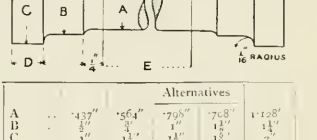
Iron or mild-steel flats and rounds machined for testing.



A any diameter up to 2".
B should be at least ¼" larger in diameter than A, but must not exceed 2½" diameter.

TABLE 4

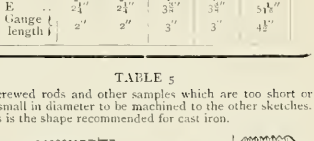
General loco. and other forgings, and other round and square bars of large section, axles, tyres, cast-steel wheel centres, and general steel castings.



	Alternatives				
A	·437"	·564"	·796"	·768"	1·128"
B	½"	⅝"	1"	1¼"	1½"
C	1"	1¼"	1½"	1⅝"	2"
D	½"	½"	⅝"	⅝"	1"
E	2¼"	2¾"	3¾"	3¾"	5⅛"
Gauge length	2"	2"	3"	3"	4½"

TABLE 5

Screwed rods and other samples which are too short or too small in diameter to be machined to the other sketches. This is the shape recommended for cast iron.



Dia.							
A	1·128"	1·000"	·798"	·750"	·564"	·500"	·437"
C	1⅛"	1"	1¼"	1"	⅝"	½"	⅜"

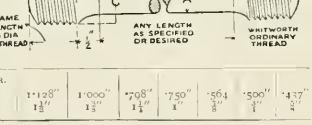


TABLE 6

Established or specified sizes

Material.	A.	E.
	Width.	
Iron and mild-steel plates, angles, &c. ..	1½"	8"
Copper plates	1½"	8"
Loco. forgings, shafting, round and square bars of large section, angles, tyres, cast iron	Dia.	3" or 2"
	·798"	
Copper stays (for fireboxes)	·564"	2"
Cast iron Transverse test	3' 6" × 2" × 1" or 14" × 1" × 1"	

SPECIAL NOTE

All samples that are machined in the centre should be parallel 1½ times the specified length; thus 2" specified length would be made 2¼" parallel, 8" specified length would be made 9" parallel.

Samples that are too short to machine to the above dimensions should be sent to the Testing Works for preparation.

passes through the centre of the section of the test piece, and for this purpose it is advisable to machine the test pieces with heads and shoulders, or to screw the ends, and hold the test pieces with ball-and-socket holders (see sheet of forms and dimensions of test pieces, p. 5). Transverse tests, which are generally made on cast iron, should have the ends of the test pieces cast or ground into knife-edge shape in order to ensure that the centre line of the pressure is normal to the centre line of the test bar. There is no difficulty in ascertaining the different test requirements unless the elastic stress is required, and the difficulties then involved are explained later on. The load in tons at the final drop of the lever of the testing machine, or the maximum reading on the pressure gauge, indicates the maximum load, which is converted into tons per square inch by dividing by the original area in square inches. The elongation is obtained by marking gauge points on the bar before test, then measuring the increased length after test and expressing this increase as a percentage. The reduction of area is obtained by taking the difference of the smallest area of the test piece before and after the test and expressing this as a percentage. A very convenient instrument for measuring the dimensions of test pieces is the taper pyramid gauge, and the sketch on page 4 shows the type made by Messrs. Chesterman.

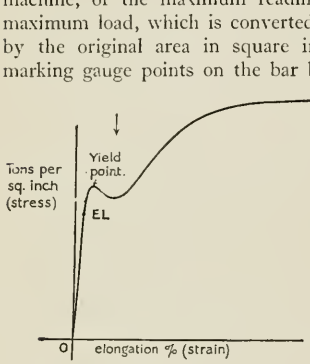


Fig. 2

Elastic Stress.—When any of the materials used in locomotive construction are subjected to tensile stress, however small, elongation takes place, and if this stress is increased by equal increments, correspondingly equal increments of elongation or strain take place, so long as the stress does not exceed the elastic stress. The *elastic limit* is, therefore, that point at which the proportionality of stress to strain ceases, and it will be evident from this definition that the accuracy with which the elastic limit is determined depends on the delicacy of the instruments employed for ascertaining the *strain*.

Beyond the elastic stress the strain takes place more rapidly than before, until we reach a point at which, in the course of testing say a mild-steel plate, the lever of a lever testing machine drops on to the bottom stop, or, in those testing machines where the stress is read from a pressure gauge, the pointer of the gauge stops momentarily, or the skin of the plate under test begins to crack. The point at which these effects take place is called the "elastic limit" in commercial tests, but this point is more or less removed from the real limit. The more rapidly the stress is applied the higher the commercial elastic limit. This commercial elastic limit is now

generally known as the *yield point*, and is in some specifications defined as the stress which gives a permanent set to the test piece of $\frac{1}{200}$th of the gauge length. The diagram (fig. 2) of stress and strain shows the different points involved.

From O to EL the diagram is a straight line, and the strain is proportional to the stress. Beyond EL, the diagram continues about the same angle, but is slightly curved, until at the *yield point* the strain takes place so rapidly that the stress falls, but soon reaches a minimum, when the

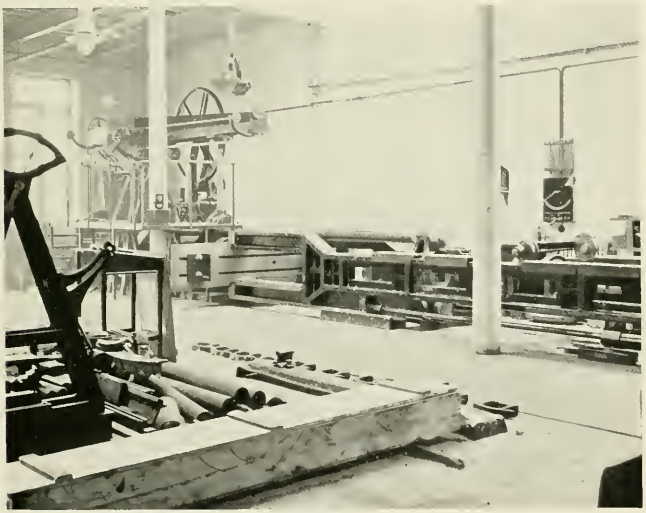


Fig. 3.—200-tons Tensile, Transverse, Compression, and Torsion Testing Machine at the Sheffield Testing Works

curve again rises until we reach the *maximum stress*. At this point the test piece begins to contract locally, the strain takes place rapidly, and the stress falls until rupture finally occurs. The breaking stress given in test reports of mild steel, or any ductile material, is the maximum stress, and not the stress at moment of rupture.

Testing Machines.—The machines used for tensile tests are now fairly well known to all engineers engaged on matters relating to locomotive construction, and are divided into the *vertical* and *horizontal* types. Most of the modern tensile testing machines can also be used for compression and transverse tests, and some are also adapted for torsion tests. Fig. 3 is an illustration of the 200-tons horizontal testing machine (Wicksteed pattern), which is one of the testing machines used at the

Sheffield Testing Works, and is adapted for tensile, transverse, compression, and torsion tests.[1]

Chemical Analyses.—In taking samples for chemical analyses it is usual to take representative drillings or turnings from the materials to be supplied. The surface of the material should be first removed and discarded. Newly ground drills or tools with any fash or wire edge on them should be avoided, to prevent any part of the drill or turning tool getting into the samples. Filings, from which particles of the file (especially in the case of hard materials) are liable to get mixed up with the drillings, should be avoided.

It very often happens that samples sent to analytical chemists for analyses are of insufficient quantity to make a desirable number of check tests, and engineers are very often without anything to guide them as to the quantity of samples required for the various analyses. The following particulars and suggestions as to these quantities, as adopted by the Sheffield Testing Works, may be found useful:

TABLE I.—STEEL AND IRON

(*Including all Classes of Steel and Cast Iron*)

Analysis Required.	Minimum Quantity.	Preferred Quantity.	Remarks.
Commercial Complete ...	2 oz.	3 oz.	All drillings to be taken under strictly clean conditions, and must be perfectly dry, i.e. no lubricant should be used when taking drillings for chemical analysis.
Full Complete	3 oz.	4 oz.	
Colour Carbon	$\frac{1}{8}$ oz.	$\frac{1}{4}$ oz.	
Silicon			
Sulphur			
Phosphorus ...	$\frac{1}{2}$ oz.	$\frac{3}{4}$ oz.	
Copper	for each	for each	
Tungsten ...	element.	element.	
Chromium ...			
Molybdenum ...			
Manganese ...	$\frac{1}{4}$ oz.	$\frac{1}{2}$ oz.	
Iron	$\frac{1}{4}$ oz.	$\frac{1}{2}$ oz.	
Aluminium ...			
Arsenic			
Vanadium... ...	1 oz.	$1\frac{1}{2}$ oz.	
Titanium	each.	each.	
Nickel			
Combustion Carbon ...	$\frac{1}{2}$ oz.	1 oz.	The drillings must be finely divided and absolutely free from dust, dirt, oil, &c.

Table 2.—STEEL-MAKING ALLOYS

(Including Ferro-silicon, Silico-spiegel, Ferro-manganese, Ferro-chrome, Ferro-tungsten, Ferro-nickel, and Ferro-vanadium)

Analysis Required.	Minimum Quantity.	Preferred Quantity.
Complete	3 oz.	$4\frac{1}{2}$ oz.
Single Element	$\frac{1}{2}$ oz.	1 oz.

Table 3.—ENGINEERING ALLOYS

(Including Refined Copper, Brasses, Muntz Metal, Gun Metal, Bronzes, &c.)

Analysis Required.	Minimum Quantity.	Preferred Quantity.	Remarks.
Complete	2 oz.	$2\frac{1}{2}$ oz.	
Copper	$\frac{1}{8}$ oz.	$\frac{1}{4}$ oz.	
Tin, Antimony, Bismuth, Lead, Iron, Arsenic	1 oz. for each element.	$1\frac{1}{2}$ oz. for each element.	Great care must be taken in drilling these Alloys not to let any iron or steel drillings get mixed with the samples.
Zinc	$\frac{1}{8}$ oz.	$\frac{1}{4}$ oz.	
Sulphur	$\frac{1}{4}$ oz.	$\frac{3}{4}$ oz.	
Phosphorus	$\frac{1}{2}$ oz.	$\frac{3}{4}$ oz.	

Note.—In most cases it is preferable that samples of the metals should be sent in their undivided state, so that drillings or parings can be suitably taken at the testing works.

Table 4.—COAL AND COKE

(Specific Gravity, preferably in Pieces about $\frac{1}{2}$ oz. in Weight)

Analysis Required.	Minimum Quantity.	Preferred Quantity.	Remarks.
Complete	4 oz.	1 lb.	The sampling should always be done by an experienced sampler. Coke to be selected by taking complete sections.
Ash	2 oz.	4 oz.	
Sulphur	2 oz.	4 oz.	
Moisture	2 oz.	4 oz.	
Phosphoric Acid	2 oz.	4 oz.	
Volatile Combustible Matter	2 oz.	4 oz.	

Table 5.—REFRACTORY MATERIAL

(Including Ganister, Silica Brick, Magnesia Brick, Fireclay, Dolomite, Limestone and Sand)

In the case of Bricks, the whole brick should be sent for analysis. For Ganister, &c., several portions should be taken from different parts of the bulk. If single elements only are to be determined, it is better that the same quantity be sent as for a complete analysis, to ensure a representative analysis.

Table 6.—CEMENT

(About 5 lb. is the Preferred Quantity)

Samples sent for analysis must be in air-tight cases, preferably made of tinned sheet.

Table 7.—OILS: HEAVY AND LIGHT

(Including all Mineral and Vegetable Oils, Rape, Linseed, &c.; Dressings, Turpentines, Naphthas, Petrol, Resin Spirits, Alcohol, Ether, and Methylated Spirits)

Minimum Quantity.	Preferred Quantity.
½ pt.	1 pt.

Table 8.—PAINTS AND VARNISHES

(Including all Classes of Paints and Varnishes used in Engineering Work)

Minimum Quantity.	Preferred Quantity.
¼ lb.	1 lb.

Table 9.—GREASES, TALLOW, ETC.

Minimum Quantity.	Preferred Quantity.
¼ lb.	½ lb.

Table 10.—WATERS

Minimum Quantity.	Preferred Quantity.
½ gal.	1 gal.

The vessel or vessels (which should be glass-stoppered bottles) must be perfectly clean and be rinsed out two or three times with some of the water which is to be analysed, before being filled. The bottles should be nearly but not quite filled, the stoppers being fastened by string or a piece of clean linen.

Investigations of Materials which have been in Use.—In addition to tests of new materials which it is proposed to use in the construction of locomotives, it often occurs that it is necessary to make investigations to find out for future guidance why certain materials or parts have behaved badly in use or have behaved extremely well. In these investigations mechanical, chemical, and microscopical analyses are often required.

In the case of a locomotive axle which had failed after a short mileage, it was recently found by the writer that the failure was due to the segregated nature of the steel. This is shown by fig. 4, in which the section has been polished and etched, and also by the micro-photograph fig. 5, which has a magnification of twenty-five diameters. The photographs

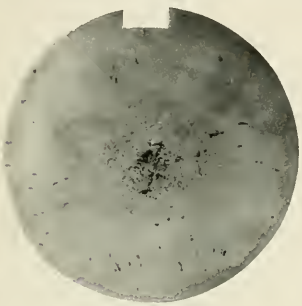


Fig. 4.—Section of Segregated Axle

Fig. 6.—Section of Normal Axle

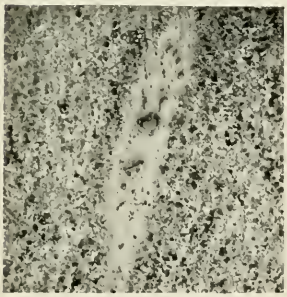


Fig. 5.—Section of Segregated Axle

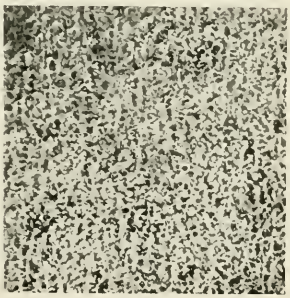


Fig. 7.—Section of Normal Axle

(Magnified 25 diameters)

shown in figs. 6 and 7 are of corresponding sections from a normal axle in which there is no appearance of segregation.

Again, fig. 8 shows a copper firebox plate which had wasted away in a very short time. In this case a chemical analysis of the deposit on the fire side showed, by the presence of a considerable percentage of sulphuric anhydride, that the fuel which had been used must have contained a very high percentage of sulphur. The unsatisfactory quality of the fuel was responsible for the wastage of the plate, and not the quality of the copper, as the writer's investigations proved it to be of a high quality.

Specified Tests.—The test requirements recommended in the British Standard Specification, Report No. 24 (revised 1921), now very commonly

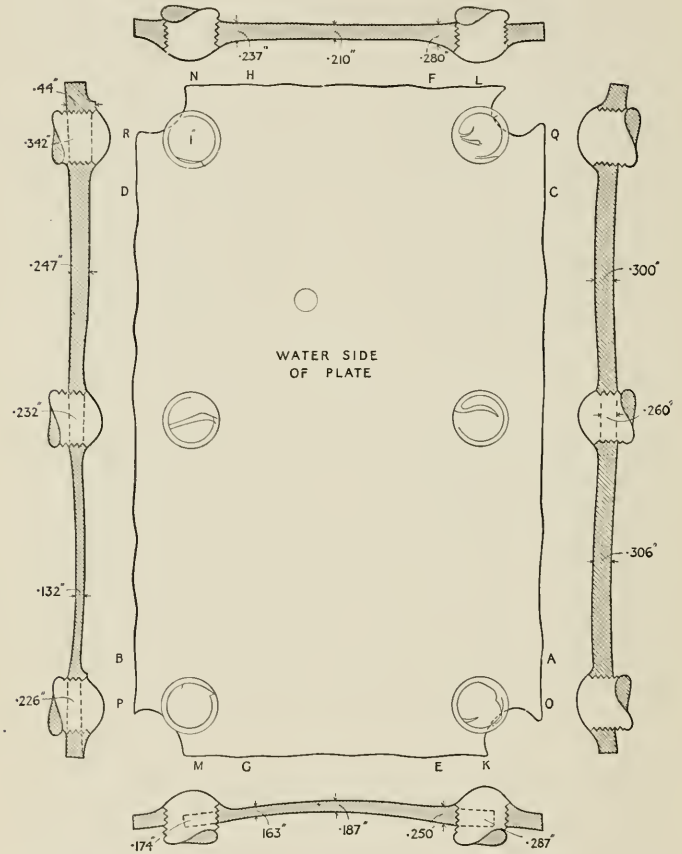


Fig. 8.—Wasted Copper Firebox Plate

govern the supply of material for locomotives, but this specification so far has not been made very complete, and only refers to axles, tyres, springs, steel forgings, steel blooms, steel castings, copper plates, rods and tubes, brass tubes, and steel plates, angles, and rivets.

The steel forgings and blooms in this British Standard Specification are divided into five classes, designated:

Class.	Description of Forging.
A	Special forgings which will be case-hardened.
B	Ordinary forgings.
C	Special forgings without wearing surfaces.
D	Special forgings with wearing surfaces.
E	Boiler forgings.

Class A includes all the forgings to be used for parts of the engine mechanism whose loads and motion are such that they must be case-hardened, but the Classes B, C, and D are not quite so clear, and are inconvenient in not having specific parts of locomotives mentioned. For instance, if one wished to turn to recommended specified requirements for double-bearing crank pins, it would not be quite clear that Class D was intended to be recommended; in fact, so far as the writer's experience goes, Class D, with a minimum tensile strength of 40 tons, is scarcely to be recommended. Again, in the British Standard Specification there does not appear to be any reference to iron boiler plates, but iron is still sometimes used for locomotive boilers, especially where the feed water is of a quality that would attack steel more than iron.

Neither does the British Standard Specification give us any specified requirements for inner firebox plates of steel, no doubt because copper plates are generally used for fireboxes on English railways; but large numbers of locomotives are built in England for export which have steel fireboxes. It refers to steel boiler plates, for which the maximum tensile strength of 30 tons per square inch is permitted; but in practice, for inner firebox plates a maximum tensile strength of 28 tons per square inch is generally considered quite high enough. Cast iron, which is still largely used in locomotive construction, is also not mentioned in the British Standard Specification referred to; it is, however, thought by the writer that the following schedule of tests, covering most of the *details* which are generally subjected to test requirements, will be found convenient. Many of the following tests have been conformed to the British Standard Specification; but in all cases where they do not conform they are in accordance with requirements which have proved satisfactory in wide use.

SCHEDULE OF TESTS RECOMMENDED

Material.	Tensile Strength in Tons per Square Inch.	Elongation per Cent in 8 Inches. Minimum.	Reduction of Area per Cent. Minimum	Maximum Sulphur and Phosphorus.	Nature and Proportion of Tests.
				per cent.	
1. Mild Steel Plates for Main and Bogie Frame Plates, Angles, and Buffer Beams, &c.	28–32	20	35	0·06	1-temper[1] bending test from each plate, and 1-tensile test piece from each set of plates.
2. Mild Steel Plates for Boiler Barrels, Outer Firebox or Shells, and Smokebox Tube Plates, &c.	26–30	22	40	0·05	1-temper[1] bend and 1-tensile from every plate, and 1-sulphur and phosphorus determination from each cast by independent analyst.
3. Steel Inner Firebox Tube Plates	24–28	20	35	0·03	1-temper[1] bend and 1-tensile from every plate, and 1-sulphur and phosphorus determination from each cast by independent analyst.
4. Steel Boiler Tubes (solid drawn)	20–25	20	35	0·05	———
5. Steel for Buffers, Drawgear, Longitudinal Boiler Stays, Connecting and Coupling Rods, &c. (not to be case-hardened)	25 to 32	with 27 in 2″ or 3″ / with 20 in 2″ or 3″	45	0·06	1-tensile and 1-bend[15] from each cast.
6. Steel for Motion work, Side Rods, &c. (to be case-hardened)	22–27	25 in 2″ or 3″	40	·05	1-tensile and 1-bend[15] from each cast. (See Note[2] *re* Steel for Case-hardening at end of Schedule.)
7. Steel Piston Rods ...	32 to 38	with 25 in 2″ or 3″ / with 20 in 2″ or 3″	35	0·05	1-tensile and 1-bend[15] from each cast.
8. Steel for Valve Gear, Spring Gear, Brake Gear, Buffing and Drawgear, and Regulator Rods, &c. (not to be case-hardened)	25 to 32	with 27 in 2″ or 3″ / with 20 in 2″ or 3″	45	0·06	1-tensile and 1-bend[15] from each cast.
9. Steel Straight Axles ...	35–40	25–20 in 2″ or 3″	35	0·05	1-falling weight test[3] from which 1-tensile is also to be cut from each cast, or not less than 2 per cent of the order.
10. Steel Crank Axles ...	32 min.	22 in 2″ or 3″	35	0·04	2-tensile and 2-bend tests (described below),[4] from each axle.
11. [5]Steel Crank Pins with double bearings (Whitworth's Fluid-pressed Steel) before hardening	36	25 in 2″	—	—	1-tensile test piece for each 5 engines.
12. Steel Slide Bars (not to be case-hardened)	32 to 38	with 25 in 2″ or 3″ / with 20 in 2″ or 3″	30	0·05	1-tensile and 1-bend[15] from each cast.

For Notes see p. 16 *et seq.*

SCHEDULE OF TESTS RECOMMENDED (*Continued*)

Material.	Tensile Strength in Tons per Square Inch.	Elongation per Cent in 8 Inches. Minimum.	Reduction of Area per Cent. Minimum.	Maximum Sulphur and Phosphorus.	Nature and Proportion of Tests.
				per cent.	
13. Hard Steel Tyres—					
Class C ...	50–55	13–11 in 2″	10	0·05	1-falling weight test[6] from which 1-tensile is also to be cut from each cast, or not less than 2 per cent of the order.
Class D ...	56–62	10–8 in 2″	10	0·05	
Class E ...	63–69	10–8 in 2″	10	0·05	
14. Steel Laminated Springs	40–50	10	20	0·05	1-tensile test from every 30 or less springs, each spring also being subjected to compression test.[16]
15. Steel Bars and Rivets ...	24–28	27	35	0·06	1-tensile test piece from each size of rivet for every 5 engines, also hot and cold bend tests. Rivets to be capable of being bent double hot or cold.
16. Steel Volute and Helical Springs	—	—	—	0·05	Tensile test not particularly to be recommended, the chemical analysis being the better check of the quality. In addition to the maximum sulphur and phosphorus recommended, the carbon should not be less than 0·8 per cent or more than 1·3 per cent, silicon 0·20 per cent, or manganese 0·5 per cent. Compression test.[17]
17. Steel Castings (with wearing Surfaces	35 min.	10 in 2″	—	0·07	1-tensile and 1-bend[7] test from each charge.
General Castings	26 min.	15 in 2″	—	—	
18. Wrought-iron Plates for Boiler Barrels, Outer Firebox Shells, and Smokebox Tube Plates, &c. (best Yorkshire Iron)[8]	20–23 (with grain)	15	20	—	1-tensile and 1-bend[9] test from every plate.
	19 min. (across grain)	12	12	—	
19. Wrought Iron for Buffers, Foundation Rings, Drawgear, Side Chains, Firebox Stays, Side Rods, Brake Gear, Boiler Angles, Spring Buckles, Spring Links. Rivets, Longitudinal Stays, and Iron Motion work, &c., for case-hardening (best Yorkshire Iron)[8]	22–24	20	30	—	1-tensile test piece from the material representing each of these parts for each 5 engines.
20. Swedish Charcoal Iron Boiler Tubes	19–24	27	50	—	Tensile tests from 2 per cent of the tubes, and mechanical tests as specified in Note [10], and each tube to be tested by hydraulic pressure.

SCHEDULE OF TESTS RECOMMENDED (*Continued*)

Material.	Tensile Strength in Tons per Square Inch.	Elongation per Cent in 8 Inches Minimum	Reduction of Area per Cent. Minimum.	Maximum Sulphur and Phosphorus.	Nature and Proportion of Tests.
				per cent.	
21. Cast-iron Cylinders, Steam Chests, Exhaust Pipes, Bogie and Tender Axleboxes, &c.	11 min.	—	—	—	1 test bar[11] to be cast on each cylinder, and 1 bar with each melting of general castings. Each cylinder to be tested by hydraulic pressure.[12]
22. Copper Plates for Inside Fireboxes	14 min.	35	45	—	1 hot and 1 cold bend[13] test from every plate. 1 tensile from each set of plates and 1 chemical analysis from each tensile.

23. Copper Tubes to contain not less than 99 per cent copper and 0·35 per cent to 0·55 per cent arsenic. One per cent of each diameter of the tubes ordered to be selected for testing, and to withstand bulging 25 per cent, and flanging 40 per cent, also to withstand, both cold and at a red heat, being flattened down until the interior surfaces of the tube meet, and then to be doubled over on itself. Each tube to withstand an internal hydraulic pressure of 750 lb. per square inch.

23*a*. Copper Pipes to contain not less than 99·25 per cent copper and 0·25 per cent to 0·45 per cent arsenic. One per cent of each diameter of the pipes ordered to be selected for testing, and withstand bulging 25 per cent, also to withstand, both cold and at a red heat, being flattened down until the interior surfaces of the pipe meet, and then to be doubled over on itself. Each pipe to withstand an internal hydraulic pressure of 600 lb. per square inch.

24. Brasses, Gun Metal, and other Alloys used for bearings of Axleboxes, Side Rods, Piston and Valve Rods, Metallic Packings, &c. (See Note [14] below.)

25. Brass Boiler Tubes to be composed either of 70 per cent copper and 30 per cent zinc approximately, with not more than a total of 0·75 per cent of materials other than copper and zinc, or not less than 66·7 per cent copper and 33·3 per cent zinc approximately, with not more than a total of 0·75 per cent of materials other than copper and zinc. One per cent of each diameter of the tubes to be selected for testing, and to withstand bulging 25 per cent, and flanging 25 per cent, also to withstand, when cold, being flattened down until the interior of the surfaces of the tube meet, and then to be doubled over on itself. Each tube to withstand an internal hydraulic pressure of 750 lb. per square inch.

26. Steam Pressure Gauges. All Steam Pressure Gauges should be graduated and tested to double their working pressure.

[1] The temper bending tests referred to must be heated to a cherry-red heat, say about 1000° C., quenched in water at 82° F., and stand bending double from the straight, with an inner radius of 1½ times the thickness of the plate.

[2] **Steel for Case-hardening.**—The intention of using mild steel for case-hardening is that a hard wearing surface be obtained, penetrating, say, from ¼₆ in. to ⅛ in. deep, whilst maintaining a soft inner core to guard against brittleness. It will generally be found that where the tensile strength exceeds 27 tons per square inch, the steel, when quenched for case-hardening purposes, is very liable to harden through its whole section, and a soft inner core is not then obtained.

[3] **Falling-weight Test for Straight Axles.**—Axles placed upon bearings must withstand, without fracture, five blows from a falling weight of 2240 lb. as specified below. The axle shall be turned after the first and third blow, and shall be broken after testing, both in the centre and at the journals.

Diameter of Axle at Centre.	Number of Blows.	Height of Fall in Feet.	Distance between Supports.
Under 4 in	5	16	3 ft.
4 in. and under 4¼ in.	5	18	3 ft. 6 in.
4¼ in. .. 4½ in.	5	20	3 ft. 6 in.
4½ in. .. 4¾ in.	5	22	3 ft. 6 in.
4¾ in. .. 5 in.	5	24	3 ft. 6 in.
5 in. .. 5¼ in.	5	24	4 ft.
5¼ in .. 5⅝ in.	5	28	4 ft.
5⅝ in. .. 5¾ in.	5	28	4 ft. 6 in.
5¾ in. .. 6 in.	5	32	4 ft. 6 in.
6 in and over.	5	35	5 ft.

[4] A test piece 9 in. long and $1\frac{1}{4}$ in. square, with $\frac{1}{8}$ in. radius at the corners, machined cold lengthwise from each web of each **Crank Axle**, must withstand being bent cold by direct pressure from a tool 2 in. wide, the end having a radius of 1 in., until the sides of the test piece are parallel. The ends of the test piece are then to be brought together without fracture, by direct pressure. As an alternative the test piece, on supports 6 in. apart, must withstand, without fracture, twenty blows from a weight of 1120 lb., having a rounded end $1\frac{1}{2}$ in. radius, falling 6 in. The test piece to be reversed after the first and every alternate blow. The fall then to be increased to 12 in. and test continued until fracture.

[5] The **Crank Pins** to be rough machined, and have a hole bored through the centre along the whole length $1\frac{7}{8}$ in. diameter, and to be then returned to the makers for oil-hardening, after which a plug is to be fitted as shown (fig. 9).

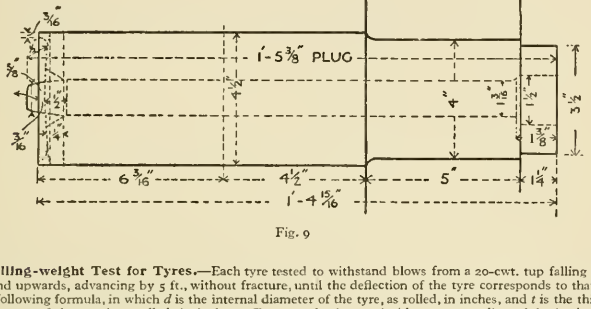


Fig. 9

[6] **Falling-weight Test for Tyres.**—Each tyre tested to withstand blows from a 20-cwt. tup falling 10, 15, 20 ft. and upwards, advancing by 5 ft., without fracture, until the deflection of the tyre corresponds to that given by the following formula, in which d is the internal diameter of the tyre, as rolled, in inches, and t is the thickness of the centre of the tread, as rolled, in inches. For tyres having an inside snip exceeding $1\frac{1}{2}$ in. in depth the calculated deflection shall be reduced by 5 per cent, and, for tyres having an inside snip exceeding $1\frac{1}{2}$ in. in depth, by 10 per cent.

Class C. Tensile Breaking Strength, 50 to 55 Tons per Square Inch.	Class D. Tensile Breaking Strength, 56 to 62 Tons per Square Inch.	Class E. Tensile Breaking Strength, 63 to 69 Tons per Square Inch.
$\frac{d^2}{50t^2}$	$\frac{d^2}{55t^2}$	$\frac{d^2}{60t^2}$

[7] Test pieces 1 in. diameter must stand being bent through an angle of 90 degrees, with an inner radius of $2\frac{1}{2}$ in., without fracture. In addition to the maximum sulphur and phosphorus recommended above, the silicon should not exceed 0·25 per cent, carbon 0·40 per cent, or manganese 0·60 per cent.

[8] The term " best Yorkshire Iron " is here used as being iron of that brand manufactured by Messrs. Robert Heath and Lowmoor, Ltd., Taylor Bros., or The Monkbridge Company, of Leeds.

[9] Test pieces cut lengthwise of the plate must withstand being bent to a curve, the inner radius of which is $1\frac{1}{2}$ times the thickness of the specimen, without fracture.

[10] The tubes to be capable of being flattened till the sides are close together and expanded hot 10 per cent and cold 5 per cent. They should also be capable of being welded together, and each tube should also be capable of withstanding a hydraulic pressure of 700 lb.

[11] **Transverse Tests.**—Bars 1 in. × 1 in. placed on 12-in. bearings to withstand, without fracture, a load of 24 cwt., with a minimum deflection of 0·07".

[12] **Hydraulic Tests of Cylinders.**—Each high-pressure cylinder to withstand hydraulic pressure of 250 lb. per square inch half an hour without leakage, and low-pressure cylinders 200 lb. per square inch.

[13] The bend tests to consist of bending double, flat, cold, and at a red heat, without fracture, and the chemical analysis to show not less than 99 per cent of copper, and 0.35 per cent to 0.55 per cent arsenic for plates of Class A, and 99.25 per cent of copper, and 0.25 per cent to 0.45 per cent arsenic for plates of Class B.

[14] These materials are not generally subjected to mechanical tests, but are expected to be of certain chemical compositions about which different railway engineers form a variety of opinions, but the following chemical compositions can be recommended:

	Copper.	Zinc.	Tin.
For Axleboxes and Side-rod Bearings	81–86 per cent.	1–4 per cent.	10–15 per cent.
For Slide Valves	83–87 ,,	·05–1 ,,	10–15 ,,
For White Metal	3–6 ,,	50–60 ,,	25–45 ,,

[15] A test piece 9 in. long × 1¼ in. square, with $\frac{1}{16}$ in. radius at the corners, machined cold, must, without any reheating, withstand being bent cold by direct pressure from a tool 1½ in. wide in the case of 22–27 and 25–32 tons tensile material, 1¾ in. wide in the case of 32–38 tons tensile material, and 2½ in. wide in the case of 40–45 tons tensile material, the ends having a radius respectively of ¾ in., ⅞ in., and 1¼ in., until the sides of the test piece are parallel. The ends of the test pieces for all forgings except those of 40–45 tons tensile shall then be brought together without fracture by direct pressure.

[16] The spring is tested by being deflected by a quick-acting scrag, before the buckle is put on, to an amount equal to $\frac{L^2}{900t}$ where L is the curved length of the top plate in inches, and t is the thickness of the thickest plate in inches. It must then stand being deflected again three times in quick succession without showing any permanent set.

[17] Each spring to be tested by being driven home once by a quick-acting scrag, the height being carefully noted after release. The spring must then stand being driven home again five times in quick succession without showing any permanent set. Up to 5 per cent of the springs shall also be tested under varying loads to determine the range and deflection per ton.

MODERN LOCOMOTIVE DESIGN

BY

A. R. BELL, Mem. Inst. Loco. Eng.

Modern Locomotive Design

CHAPTER I

The Evolution of the Modern Locomotive

In discussing the subject of modern locomotive design it will be well to consider in the first place the conditions the designer of to-day is called upon to meet. These conditions relate mainly to questions affecting:

1. The nature of the traffic to be dealt with.
1. The weight of the trains to be hauled.
3. The speed at which it is desired to run.
4. The contour of the road and character of the track.
5. The limits within which construction is permissible.

Nature of Traffic.—The nature of the traffic to be dealt with is the determining factor in the problem, and dictates at once the main lines upon which the designer works. Fast through traffic, either passenger or goods, over long stretches, probably in direct competition with other railways serving the same area; lengthy journeys with more or less frequent stops *en route*, but still with a necessity for fast running between points of call; short trips on a continuous schedule in areas of congested traffic; passenger traffic calling for the haulage of heavy vehicles of special construction; goods or mineral trains involving the use of wagons of exceptional design: these are but some of the many classes of traffic for which the locomotive engineer is called upon to provide motive power, and in designing suitable locomotives for the purpose he has to regard the particular traffic concerned in relation to each of the other considerations of which mention has been made, and, no doubt, additional points which, although not so generally applicable, may locally assume a most important aspect.

Weight of Trains.—The weight of the trains to be hauled is at once a very important and a very uncertain factor, and has to be considered in conjunction with the rate of speed at which it is desired to run and the prominent characteristics of the road over which the trains are to travel. There has been no more marked feature in the development of railway working than the constantly increasing weight of the train load, whether it be of passengers or goods, and accordingly the wise designer, with an eye to the future, provides such a reserve of power in his engines as will enable

them to cope with the heavier loads they will almost inevitably be saddled with before they have run their course. Thirty years ago express trains rarely exceeded a weight of 120 tons behind the tender; to-day we have locomotives as heavy (including their tenders) as these trains, hauling at high speeds loads of 400 tons and upwards. The advance in the weight of goods trains has been equally striking, and there has consequently been a corresponding increase in the haulage capacity of the locomotives provided for that traffic.

High-speed Running.—Speed considerations are, of course, largely dependent on the nature of the traffic, the weight of the load, and the contour and character of the track. Sustained running at comparatively high speeds was by no means unknown many years ago. It is the maintenance of the speed standard with the far heavier loads and the largely increased number of trains run at high speeds, rather than an advance in the actual rate of speed, that has been so characteristic of modern railway working.

Character of Permanent Way.—With the heavy trains to be hauled at sustained high speed over long runs, the nature and strength of the permanent way and the length and severity of the gradients become matters of moment to the locomotive designer. Much has been done to assist him. On more than one of our great trunk lines the road bed of to-day is of immeasurably superior character to that of, say, twenty years ago, and where new routes have been laid down the matter has invariably been viewed as of first importance. Bridges and culverts have been strengthened. Rails weighing from 85 to 105 lb. to the yard have replaced the 75-lb. rails previously the virtual standard. Not a little, especially in laying down new railways, has been done to "soften" gradients, avoid sharp curves, and generally to allow the locomotive engineer as much "elbow room" as possible. But when all is done, modern railway working demands that he shall furnish locomotives capable of so dealing with heavy loads on severe adverse gradients as to maintain the high over-all rate of speed entailed by the time schedule, with as little recourse as possible to exceptional running over the more favourable portions of the road or to the expedient of "double-heading" or "banking"; that is, the employment in front or rear of the train of an assistant engine to surmount severe gradients.

Gauge Restrictions.—And, lastly, the designer's efforts are, in this country, "cabin'd, cribb'd, confined" within the limits of construction entailed by the presence of various wayside or over-line structures. More and more have locomotive engineers found it necessary in recent years to take full advantage of the available space within loading-gauge limits, and the steps recently taken by several of the companies to extend those limits in some degree is significant of the times.

Earlier Efforts to meet Modern Requirements.—The earlier attempts to cope with the marked demand for greater locomotive power in Britain were somewhat tentative in nature and were directed almost exclusively towards the more effectual use of the steam raised in the boilers then existing, whilst little attempt was made to provide increased boiler

power. As a consequence the traffic outgrew the power of the locomotives, and " double-heading " became the usual order of things with most of the important trains. It was but slowly that the urgent necessity of larger steam-generating capacity with an accompanying increase in the weight available for adhesion was recognized and means found to supply it. The most powerful British express-locomotive boiler reported to the International Railway Congress of 1895 was that used by Mr. F. W. Webb in his " Greater Britain " class of three-cylinder compound engines. The total heating surface provided by these boilers was 1505·7 sq. ft.; in Mr. Churchward's " Pacific " locomotive on the Great Western the total heating surface is 3400·81 sq. ft. In the development of the locomotive boiler during the past eighteen years, at first gradual but subsequently by leaps and bounds, is contained most that is essential in the history of modern British locomotive practice. Viewing for the present purpose the matter as one strictly confined to the mere question of steam-raising surface, the following table will serve to show the progress made since that date in the power of locomotive boilers of any description:

TABLE I

LARGEST HEATING SURFACE IN BRITISH LOCOMOTIVES, 1896–1920

Year.	Railway.	Designer.	Type of Locomotive.	Heating Surface.
				sq. ft.
1896	Highland	D. Jones	4—6—0 two-cylinder simple (goods) (*a*) ...	1672·5
1897	L. & S.-W.	D. Drummond ...	4—2—2—0 four-cylinder simple, 720 class (*b*) (*c*)	1690·4
1898	Gt. West.	W. Dean	4—4—0 two-cylinder simple, "Bulldog" class (*d*)	1656·91
1899	L. & Y.	J. A. F. Aspinall...	4—4—2 two-cylinder simple, 1400 class ...	2052·8
1900	Highland	P. Drummond ...	4—6—0 two-cylinder simple, "Castle" class ...	2050
1901	Caledonian	J. F. McIntosh ...	0—8—0 two-cylinder simple, 600 class (mineral)	2500
1902	Gt. West.	W. Dean	4—6—0 two-cylinder simple, No. 100 (*e*) ...	2410·31
1903	Gt. North.	H. A. Ivatt ...	4—4—2 two-cylinder simple, No. 251 class (*f*)	2500
1904	N.-Eastern	W. Worsdell ...	4—4—2 two-cylinder simple, No. 532 class ...	2455·8
1905	L. & S.-W.	D. Drummond ...	4—6—0 four-cylinder simple, 330 class (*c*) ...	2727
1905	Gt. West.	G. J. Churchward	4—4—2 four-cylinder compound, No. 40 ...	2735·7
1906	Caledonian	J. F. McIntosh ...	4—6—0 two-cylinder simple, 903 class... ...	2360
1907	Gt. West.	G. J. Churchward	4—6—0 four-cylinder simple, "Star" class ...	2142·91
1908	Gt. North.	H. A. Ivatt ...	4—4—2 four-cylinder compound, No. 1421 (*g*)	2351·8
1909	L. and Y.	G. Hughes ...	4—6—0 four-cylinder simple, 1506 class ...	2507
1910	N.-Eastern	W. Worsdell ...	4—4—2 two-cylinder simple, 696 class ...	2456
1911	L.B. & S.C.	D. E. Marsh ...	4—4—2 two-cylinder simple, 421 class... ...	2511
1912	N.-Eastern.	V. L. Raven ...	4—4—2 three-cylinder, 717 class (*c*)	2340
1912	L. & S.-W.	D. Drummond ...	4—6—0 four-cylinder, 443 class...	1076
1913	L. & N.-W.	C. J. Bowen Cooke	4—6—0 four-cylinder, "Claughton" class ...	1649
1914	L.B. & S.C.	L. B. Billinton ...	4—6—4 tank	1687
1916	Metropolitan	C. Jones	0—6—4 tank	1181
1917	Caledonian.	W. Pickersgill ...	4—6—0 62 class	1934·25
1918	Gt. North.	H. N. Gresley ...	2—8—0 three-cylinder, 461 class	2521
1919	Gt. West.	G. J. Churchward	2—8—0 4700 class	2171·43
1920	L. & S.-W.	R. W. Urie ...	4—6—0 496 class...	1878

(*a*) First of class built in 1894.
(*b*) Coupling rods not used. Two cylinders inside the frames drive the forward pair of driving wheels; two cylinders, placed outside, drive the remaining pair.
Rebuilt in 1905 with larger and higher-pitched boiler, having 1760 sq. ft. of heating surface.
(*c*) Water-tubes in the firebox. (*d*) Serve tubes.
(*e*) Converted by Mr. Churchward to standard coned boiler, with heating surface of 2142·91 sq. ft.
(*f*) Ignoring Great Eastern experimental 0—10—0 (" Decapod ") tank engine. Heating surface of this engine 3010 sq. ft.
(*g*) Ignoring Great Western 4—6—2 four-cylinder simple " Great Bear ", No. 111.

Higher Steam Pressures.—Accompanying the adoption of large boilers there has been a decided tendency towards the use of higher steam pressures. A boiler pressure of 175 lb. per square inch was unknown in any British locomotive prior to 1884, when Mr. Webb introduced his "Dreadnought" class of three-cylinder compounds, and it was not till 1889 that so high a pressure was tried in a simple engine. In 1898 Mr. Dean advanced from 165 to 180 lb. for simple engines; in the following year Mr. Worsdell adopted 200 lb. in place of 175 lb.; whilst Mr. Churchward, when rebuilding Mr. Dean's "Badminton" class in 1903, took the opportunity to supply boilers pressed to 210 lb., and in the following year, when building the 4—6—0 simple locomotive "Albion" for trial in comparison with the French compound "La France", he tried 225 lb. in the simple as against 227·5 lb. in the compound, and has maintained this pressure as standard with all his four- and two-cylinder 4—6—0 passenger engines and his 2—8—0 freight engines. A few years ago it seemed likely that ultimately the steam pressure would, on most of the lines, be raised to 200 lb. per square inch, but the almost universal adoption of superheating apparatus has arrested this tendency, and designers eagerly welcome the opportunity to mark down the figure. With the higher steam pressures had come, almost as a direct consequence, a somewhat alarming increase in the bill for boiler maintenance, especially where waters were hard. Some valuable experiments carried out by Professor Goss at the Purdue University went to show that waters of a magnesian or calcareous nature are most destructive in their action with pressures of 200 lb. and upwards, whilst comparatively harmless at 140 lb., and also that, although with the higher pressures there is a decrease in the consumption of fuel and water per i.h.p. hour, the saving by no means increases at the same rate as the rise in the pressure. Some relief could, of course, be found by the installation of water-softening plant, and much has been done in this direction on the Great Western and elsewhere. But seeing that it is possible by the employment of superheating apparatus to obtain the same power output with the lower as with "saturated" steam used at the higher pressures, the last few years have witnessed a set-back in the steam pressures to 180 lb., 160 lb., and even 140 lb. per square inch. Higher pressures are often still used abroad in conjunction with superheating, but this is mainly in compound engines.

Fireboxes.—Another point of practice concomitant with the development of the locomotive boiler as a whole is the virtual supersession of the old round-topped or Crampton form of firebox in new design. With the higher steam pressures used, the need of as large a steam space as possible at the crown of the box became more and more apparent, and something of the nature of the Belpaire form of firebox, with its flat-topped outer casing and simplified staying, was soon regarded almost as a necessity The first British locomotive engineer to adopt the Belpaire firebox was Mr. H. Pollitt, who some twenty-one years ago introduced this form on the Manchester, Sheffield, and Lincolnshire (now Great Central) Railway.

The Belpaire box has since remained standard practice on that line, and has, either in its original or in some modified form, been widely adopted by other builders. This form of firebox has not always proved an unmixed blessing, and in early days some trouble was experienced owing to the rigid staying of the roof of the box preventing to a certain extent the vertical movement of the crown plates due to varying temperature. The Great Western has standardized a very large Belpaire firebox in combination with a coned boiler.

Other Firebox Developments.—Firebox development has also proceeded in other directions; indeed, more attention has perhaps been given to this question in recent years than to any other in the whole range of locomotive design. The increased diameter of the boiler barrel has involved the widening of the upper part of the firebox; but, in addition, larger firebox areas and grate surfaces have been sought in two directions —the wide firebox, comparatively short and shallow, extending over the frames and wheels, or the long narrower box sloping up over the axles behind the driving wheels. The wheel arrangement forms to a large extent the determining factor in the choice. Where, as in America, loading-gauge considerations may be practically ignored, the wide firebox is largely used, inasmuch as it can if desired be mounted above wheels of comparatively large diameter. Many American engines of the 4—6—0 type have wide fireboxes placed over 5-ft.-9-in. wheels, a sufficient depth of throat sheet for ordinary conditions being secured by sloping the mud ring downward towards the front end between the second and third pairs of driving wheels. In this country, however, gauge limitations preclude fireboxes constructed entirely above wheels of larger diameter than 4 ft. 6 in. It is not, therefore, possible to adopt the wide firebox in British passenger engines of the 4—4—0 or 4—6—0 type, and, apart from two ten-wheeled goods engines built in 1896 and 1899 respectively by Mr. Dean, who initiated the use of the wide firebox in this country, and the experimental "decapod" tank engine built in 1903 for the Great Eastern by Mr. James Holden (all three of which engines have been broken up), the only British locomotives at present provided with wide fireboxes extending entirely over the frames are Mr. Ivatt's "Atlantics" of No. 251 class and its variants on the Great Northern, and the London Brighton and South Coast "Atlantics" built by Mr. Earle Marsh on his migration from Doncaster to Brighton. The practice, however, is very common in America, where John E. Wootten adopted it as far back as 1877, basing his design on the arrangement made in 1855 by James Millholland. The advantages of wide fireboxes are fairly obvious; their disadvantages may not be quite so apparent. Their use demands skill of the highest order on the part of the fireman to ensure the successful maintenance and management of a fire spread over so extended a grate. Moreover, the concentration of the fire in such close proximity to the tube plate has been found to lead to very considerable tube leakage, and this has sometimes been increased by injudicious spacing of the tubes. The wide firebox employed by Mr. Ivatt measured inside

at the bottom 5 ft. $2\frac{1}{8}$ in. long by 5 ft. $11\frac{5}{8}$ in. wide by 5 ft. $11\frac{1}{8}$ in deep at the back, sloping off at half its length to 3 in. deeper at the front.

Long Narrow Fireboxes.—The more favoured practice has been to lengthen the ordinary narrow firebox placed between the frames. In 1895 the fireboxes used in express locomotives varied in length inside at bottom from about 5 ft. 3 in. to about 6 ft., and rarely exceeded 5 ft. 9 in. At this time the usual Great Western and London and South-Western practice gave 5 ft. $7\frac{7}{8}$ in. Now the Great Western standard dimension is 8 ft. $2\frac{1}{2}$ in., whilst Mr. Urie, in his large 4—6—0 express locomotives, has gone to 9 ft. With these long fireboxes it is, of course, necessary to reduce the depth at the back in order to clear rear axles, and this has tended to increase leakage of stays. However, greater attention to provision for water circulation around the box has in many cases resulted in a lessening of the evil.

Shallow *v.* Deep Fireboxes.—On the general question of the design of fireboxes it may be remarked that careful tests of coal consumption for over five months' service on two London and North-Western locomotives, working under conditions as nearly as possible identical, would seem to point to the fact that the shallow firebox with large grate area produces better results than the deep firebox with smaller grate area. Here we had two engines, one four-coupled and the other six-coupled, in all essentials identical except as to wheel arrangement and design of firebox, employed under observation upon the same duty and with everything possible done to equalize working conditions. The one (an engine of the "Experiment" class of 4—6—0 wheel arrangement) with a firebox measuring 2 ft. 4 in. in depth from the centre line of the brick arch to the firebars in front, and 1 ft. $5\frac{3}{4}$ in. at the back under the tube plate, and providing a grate area of 25 sq. ft. and heating surface of 133 sq. ft., came out of the trials with an average coal consumption of 52·25 lb. per mile. The other (one of the "Precursor" type of 4—4—0 engines), in which the corresponding depths were 3 ft. $5\frac{3}{4}$ in. and 2 ft. 6 in. respectively, and the grate area and heating surface 22·4 sq. ft. and 161·5 sq. ft. respectively, consumed on an average 57·53 lb. of coal per mile. Just how much of this startling difference was due to the comparative efficiency of the two types of firebox, and how much might be due to other influences, such as wheel arrangement, was a matter which at the time evoked a large measure of illuminating discussion. Whatever the explanation, the fact remains that the engine with comparatively shallow firebox combined with an extended grate showed, when working on the same duty under conditions as identical as it was possible to secure, a saving of no less than $5\frac{1}{4}$ lb. of coal per mile over the consumption of an engine of almost identical boiler power but supplied with a deeper firebox with smaller grate.

Water Tubes.—The use of water tubes for augmenting the heating surface in British locomotives was inaugurated by Mr. D. Drummond in 1897, when, in building his first four-cylinder simple engine (No. 720) for the London and South-Western, he experimented with a series of trans-

verse water tubes in the firebox. The results led him to utilize the principle in further engines built in 1899 and 1900. In some later six-coupled four-cylinder simple engines he secured no less than 357 sq. ft. of extra heating surface by means of two nests of 56 of these tubes, $2\frac{3}{4}$ in. outside diameter. Possibly owing to additional cost of fitting and the increased depth of firebox involved in their effective use, other designers appear to have considered Mr. Drummond's transverse water tubes unnecessary. They were tried experimentally only on the North-Eastern, London Brighton and South Coast, and Highland Railways. In 1902 Mr. Drummond provided No. 373, one of his useful 4—4—0 mixed-traffic engines, with what may be called a water-tube boiler, in which, in addition to 40 transverse water tubes in the firebox, he placed no fewer than 215 in the boiler barrel, displacing by this means all but 18 of the usual fire tubes and providing a total heating surface of 736 sq. ft. as against 1290 sq. ft. for similar engines fitted with the ordinary flue tubes. Although a saving of 1 lb. of coal per mile was claimed as a result, the practice was discontinued.

There have, however, at various times been many attempts to utilize water tubes in locomotive practice abroad, and M. Asselin, on the Nord of France, employed an enormous water-tube firebox in a "Baltic" four-cylinder compound. Some years ago Herr Brotan claimed a large measure of attention with a locomotive boiler in which a system of water tubes connecting an upper cylindrical steam chamber with the foundation ring formed the two sides and back of the firebox. A small shunting tank locomotive, in the service of a smelting works in South Wales, fitted with a Brotan boiler has been at work a few years, but the practice has only been followed extensively on the Continent.

Cylindrical Corrugated Firebox.—In 1902 Mr. Hoy, on the Lancashire and Yorkshire Railway, fitted to No. 392, one of his predecessor's eight-coupled mineral engines, a steel cylindrical corrugated firebox, much on the lines of the Vanderbilt firebox used to some extent in America. The fundamental principle involved in proposals of the kind is the same as in the case of Serve ribbed tubes, namely, the utilization of the absorptive rather than distributive properties. The idea had been made use of years before, by Strong in America, by Lentz in Germany, and to a small extent by Webb in England, but in no case with successful results; and despite the advantages claimed for the box—notably a simple construction, free from stays and joints, permitting of increased facilities for water circulation —nothing further has been done in this direction, so far as British practice is concerned.

Steel for Inner Fireboxes.—No better fate has attended the efforts made at various times on British lines to substitute mild-steel plates for copper in the construction of the usual form of inner firebox, and here again we see practice all but universal throughout the North American continent failing to obtain more than a very slight following elsewhere. Steel boxes are, of course, lighter both in weight and in first cost than copper, and they offer special advantages when used with high pressures;

but they have their disadvantages, of which rapid corrosion in bad-water districts is not one of the least. This corrosion difficulty has led to attempts to utilize nickel steel for the purpose; but what advantage this material has offered is altogether outweighed by the largely increased first cost.

Steel Boiler Tubes.—Although some difference of opinion still exists among British locomotive engineers as to the best material for boiler tubes, the superior merits of the steel tube are becoming more and more recognized, and there is much less use made of brass or copper composition for the purpose.

Serve Boiler Tubes.—Mention may here be made of Serve boiler tubes, which have also been on extended trial in this country only to be rejected in the end. Their use is apparently found beneficial on the European continent, where many thousands of heavy locomotives fitted with these tubes are now working. They do not, however, appear to show the same good results when made use of in British practice, and in any case their comparatively high price must always be a matter for consideration. Mr. Dean introduced their use in British express locomotives in 1898 when building his " Badminton " class for the Great Western, and amongst other British locomotive engineers to give them a trial have been Messrs. Churchward, Johnson, Ivatt, and J. Holden.

Longer Boiler Tubes.—One of the great advantages claimed for the Serve tubes is that they render it possible to have a larger heating surface with a boiler of given size, or, in the alternative, to maintain a certain standard amount of heating surface with a smaller number of tubes. Obviously, increased surface could also be obtained by lengthening the ordinary smooth-bore tubes, but this larger surface could be turned to good account only so long as the ratio between the diameter of the tubes and their length was maintained at the proper standard for efficiency.

Small Boilers Standard Practice at 1895.—If for nothing else the quarter of a century from 1870 to 1894 will always be memorable in British locomotive history as the period during which the late Mr. Patrick Stirling built his famous 8-ft.-1½-in. single-driving engines, a typical class of which had a boiler barrel 11 ft. 5 in. long with a minimum outside diameter of 4 ft., provided with 174 copper tubes of 1¾ in. external diameter and 11 ft. 9 in. long between tube plates. But by 1895 the four-coupled simple type had fairly established itself as the standard express locomotive on most British lines, and the average length of the boiler barrel of typical engines of the kind on eighteen of the principal railways was no more than 10 ft. 5 in., the tubes employed varying from 189 of 1⅝ in. and 196 of 1⅞ in. to 254 of 1⅝ in. and 333 of 1½ in. external diameter.

There had been at this period a noticeable tendency to seek increased locomotive power rather in an enlargement of the already ample cylinders than in increased facilities for steam raising, and even when steps were taken in the more desirable direction by the adoption of larger fireboxes, it was in but few instances that the proper utilization of these large

fire-boxes was rendered possible by the provision of boilers of suitable size.

In the light of modern developments in locomotive boilers it is almost amusing to find it reported to the International Railway Congress of 1895 that " the maximum capacity of the locomotive boiler is nearly reached ", and to read that the higher pitching of boilers " cannot be accomplished on account of our bridges ". No doubt the reporter to the 1895 Congress shared at the time the opinion then freely held, viz. that British locomotive boilers could not be materially increased in size, owing mainly to the restricted loading gauge. Yet less than four years later we find that very reporter startling us with a leap forward in boiler design which, Mr. Ivatt's slightly earlier 990 class notwithstanding, gave us in No. 1400, Lancashire and Yorkshire 4—4—2 express engine, the forerunner of the long line of powerful British locomotives which has (dare we say?) culminated in Mr. Churchward's " Great Bear ".

The Birth of the Modern British Locomotive Boiler.—Prior to 1899 the heavy express work on the Lancashire and Yorkshire Railway was shared by two classes of four-coupled simple engines of no exceptional power, but in that year appeared the first of Sir John Aspinall's " Atlantics ". The advance made in these engines, so far as the boiler barrel is concerned, may be seen from the following comparative figures:

TABLE II

Class of Engine.	Diameter of Driving Wheels.	Length of Boiler Barrel.	Maximum Outside Diameter of Boiler Barrel.	Height of Centre Line from Rail.	Tubes.		Heating Surface of Tubes.
					No.	Size (External Diameter).	
	ft. in.	ft. in.	ft. in.	ft. in.		in.	sq. ft.
4—4—0	7 3	10 $7\frac{3}{8}$	4 3	7 9	220	$1\frac{3}{4}$	1108·73
4—4—2	7 3	15 0	4 10	8 $11\frac{1}{16}$	239	2	1877

It will be seen that the boiler was pitched with its centre line no less than 14 in. higher than before, notwithstanding that it was of 7 in. greater diameter, and it may also be said that despite a shortening of the exposed portion of the funnel the height of the engine from the top of the rail to the chimney top was increased from 13 ft. $1\frac{5}{8}$ in. to 13 ft. $5\frac{1}{2}$ in.

It has been remarked that the average length of boiler barrel of eighteen typical four-coupled British locomotives in 1895 was 10 ft. 5 in. only, and that there was then a decided tendency to advance rather along the lines of increased cylinder capacity than to seek enhanced boiler power.

The following table shows all that is essential in the present connection with respect to the three most powerful boilers amongst the four-coupled single-expansion engines:

TABLE III

Company.	Length of Boiler Barrel.	Minimum Diameter (outside).	Height of Centre Line above Rail Level.	Tubes.		Tube Heating Surface.	Firebox Heating Surface.
				No.	Size (External Diameter).		
	ft. in.	ft. in.	ft. in.		in.	sq. ft.	sq. ft.
L. & S.-W.	11 0	4 4	7 9	240	$1\frac{3}{4}$	1245·6	122·16
L. B. & S. C.	10 2	4 4	7 5	333	$1\frac{1}{2}$	1378·2	113·9
N.-Eastern	11 6	4 4	7 11	225	$1\frac{3}{4}$	1220·0	121·0

To-day we have boiler barrels of 15 ft. in length and 5 ft. 6 in. diameter pitched with their centre lines 9 ft. above rail level. Twenty years ago Sir John Aspinall touched the lines of the loading gauge, yet room has since been found for such monster boilers as those supplied to engines on the Great Northern, the North-Eastern, to several classes of six-coupled engines on the Scottish lines, to many of Mr. Churchward's locomotives on the Great Western, to Mr. James Holden's " Decapod " on the Great Eastern, to 4—6—0 engines on the London and South-Western, and many others. The Great Western standard coned boiler compares favourably with the Lancashire and Yorkshire pattern, which is still practically standard practice on that line. Yet how far Mr. Churchward advanced in the boiler for the " Great Bear "—England's only " Pacific "—may be gathered from the following comparison:

TABLE IV

	Length of Boiler Barrel.	Maximum Diameter (outside).	Height of Centre above Rails.	Heating Surface of Barrel.
	ft. in.	ft. in.	ft. in.	sq. ft.
Standard boiler	14 10	5 6	8 6	1988·65
" Great Bear "	23 0	6 0	9 0	3218·45

It will be seen that even at this advanced stage of the era of boiler development Mr. Churchward lengthened his barrel to the extent of 55 per cent, and increased its diameter by 9 per cent, and so utilized the means thus placed at his disposal as to secure 62 per cent more tube surface for heating purposes.

The Long Boiler.—The general increase in the length of the modern boiler, so long regarded with suspicion from the point of view of efficiency, and even now accepted in some quarters with considerable reluctance, was the direct outcome of the failure of the " single-drivers " to deal successfully with the heavier trainloads. Mr. Ivatt, it is true, endeavoured to overcome the difficulty by supplying his 7-ft.-$7\frac{1}{2}$ in. single-drivers with 11-ft.-4-in.

boilers of 4 ft. 5 in. diameter (5 in. in excess of Mr. Stirling's practice) pitched with centre line 8 ft. 3 in. above rails. The want of sufficient adhesion with a single pair of driving wheels rendered the four-coupled type inevitable, and expansion in the direction of length, more than in diameter, followed.

The long boiler was, however, even then no innovation. Mr. Sturrock used boilers 13 ft. 8⅛ in. long on some eight-coupled mineral engines on the Great Northern as early as 1866, and in 1889 boilers 13 ft. 5½ in. long were supplied to some tank engines for mineral traffic on the Barry line. In 1892 Mr. Webb was employing 15-ft.-6-in. boilers in his eight-coupled simple goods engines, but these, like the " Greater Britain " express class (commenced in the previous year and supplied with 18-ft.-6-in. boilers), had intermediate combustion chambers. The modern type of long boiler may therefore be said to have been introduced by Mr. Webb in his three-cylinder eight-coupled compound goods engines built in 1893, the boilers of which were 15 ft. 6 in. long and 4 ft. 3 in. in outside diameter. Then followed in 1894 the first British 4—6—0 engines, also for goods traffic, built to the designs of Mr. Jones for the Highland Railway, with boiler barrels 14 ft. 1⅜ in. between tube plates and 4 ft. 7⅞ in. outside diameter; Mr. Dean's 4—6—0 goods engine, No. 36, with boiler 14 ft. long and 4 ft. 6 in. diameter in 1896; and in 1899 Sir John Aspinall's four-coupled express engine, No. 1400, with a pair of trailing carrying wheels added to accommodate a boiler 15 ft. in length. Since the latter date the employment of long boilers has become common in new design, and this extended use has of course been accompanied by a corresponding increase in the number of passenger engines of the 4—4—2, 4—6—0 types, 2—4—2, 4—4—2, 2—6—2, and 4—6—2 tank types, and goods engines of the 2—6—0, 4—6—0, 0—8—0, 2—8—0, and 0—8—4— (tank) wheel arrangements.

Coned or Tapering Boilers.—An important modification in the form of the boiler has been employed on the Great Western by Mr. Churchward. He slightly widens his firebox at the front end, and employs a boiler tapering up to the enlarged firebox casing very much on the lines of the wagon-top boilers so widely used in America since Thomas Rogers introduced them in 1850. The principle had previously found expression in this country on some tank engines for the Taff Vale Railway, whilst in 1876 Mr. Bromley, when rebuilding, on the Great Eastern, No. 492—one of Mr. Johnson's six-coupled goods engines—provided it with Weston's patent boiler and firebox. In this latter case the firebox projected for a length of 4 ft 7 in. into the barrel, which was then tapered off from a diameter of 4 ft. 7½ in. to 4 ft. Mr. Churchward has pointed out that the " coned " barrel connection, in addition to providing a greater area of water line, also gives a larger steam capacity, and, by the larger diameter being arranged to coincide with the line of the firebox tube plate, much more water space is possible at the sides of the tubes, giving increased heating surface at the most valuable part of the boiler.

Dispensing with Steam Dome.—With the flat-topped firebox as used on the Great Western the space between the top of the inside firebox

and the outer casing is 2 ft. or from 30 to 40 per cent more than that usually allowed, and this increased space tends, of course, to the supply of drier steam and the prevention of priming. In fact, Mr. Churchward claimed that this increase in area at the water line at the hottest part of the boiler, combined with the coned connection to the barrel, supplied him with drier steam than could be obtained by means of the steam dome. He therefore dispensed with the dome and collects his steam at each side of the firebox casing just underneath the outer shell near the front end, using for the purpose a branched pipe with upturned mouths. With this arrangement he places the regulator in the smokebox.

Mr. Churchward is the only locomotive engineer now consistently employing the domeless boiler. The practice has never had any advocacy outside this country. Boilers without domes have been at various times extensively used on the Great Eastern, Great Northern, Great Western, Glasgow and South-Western, London and South-Western, and South-Eastern Railways, and to a slight extent on the London and North-Western. With the exception, however, of Mr. Matthew Stirling's engines on the Hull and Barnsley line, such boilers are now found in Great Western practice only. Even on the Great Western the dome had been entirely restored for new construction by Mr. Dean prior to the immediate charge of the locomotive department being handed over to Mr. Churchward. With the building of the " Waterford " in 1898, however, Mr. Churchward, acting for Mr. Dean, at once reverted to the domeless boiler and the perforated-pipe arrangement for taking steam.

The steam dome undoubtedly presents a point of weakness in the boiler by reason of the large aperture in the cylindrical form of the boiler barrel which its use entails, and from the very early days of railways endeavours have been made to obviate risk from this inherent weakness either by strengthening the boiler at this point or by removing the dome itself. As a consequence, several locomotive engineers adopted, as a means of obtaining steam as free as possible from moisture, a pipe running close to the top of the barrel inside, with perforations at intervals on the upper side of its circumference through which the steam found its way into the pipe, being " dried " as it did so. The method at times acquired a large measure of adherence, and with the advent of the " Waterford " it seemed that a fresh lease of life was to be given the perforated steam pipe. However, when building his " City " class in 1903, Mr. Churchward introduced the use of the coned boiler, and took the opportunity at the same time to dispense with the perforated pipe in favour of the branched pipe above referred to, and to this he has since adhered.

Use of Superheating.—Slight reference to this subject has already been made in connection with steam pressures. There is little doubt that pressure troubles were in some measure responsible for the recognition by British locomotive engineers of the merits of superheating, tardy though it was. For all practical purposes the use of superheated steam in locomotives may be said to date from 1898, when the Schmidt arrangement was

applied to two engines on the Prussian State Railways. Thereafter progress was rapid, not only in Germany, but also with other forms on Canadian railways and elsewhere for several years, before any serious attempt was made to introduce the principle in this country. But from 1908 onwards much has been done, and to-day there is little new construction without such provision. A persistent campaign by commercial concerns interested in the many patents has met with great success. The Robinson superheater has been fitted to all sorts and conditions of locomotives irrespective of service considerations; its adoption may almost be considered standard practice.

Cost and Efficiency.—The theoretical advantages commonly claimed for superheating in principle are the ability to employ dry steam at a temperature higher than that corresponding to its pressure, with consequent minimizing of cylinder condensation; an increase in the volume of the steam, resulting in greater efficiency in the cylinders; the opportunity afforded to utilize to a further extent a portion of the heat of the furnace gases in their passage from the tubes to the chimney. But whilst there is no doubt of the value of these advantages, in actual practice the whole is summed up in one word: economy; and there are, of course, two sides to the account. On the debit side are to be placed the first cost of the apparatus and royalty charges; maintenance and repair of the increased number of working parts involved in the application of superheating apparatus; higher cost of lubrication; provision of special designs of valves and packings. Each of these items means a fairly considerable sum of money, but experience has proved that the saving in fuel and water due to the provision of superheating does, as a matter of fact, more than compensate for the increased expenses, although doubts may reasonably be cast on some of the extravagant results claimed in some quarters. It would appear that in actual work a superheated locomotive may fairly be expected to show an advantage for identical service of 12 to 18 per cent in coal and 20 to 30 per cent in water over an engine of the same class using " saturated " steam; and this being so there can be no question as to the ultimate economy to be effected, and no reason to seek to unduly inflate the results obtained by ignoring important factors in the case. It is, indeed, quite plain that there is much room yet for the improvement and development of apparatus; and there are some points of principle which are still open to debate.

Other Considerations.—For instance, where should the superheating apparatus be placed? The earlier Schmidt arrangement was located in the smokebox, but latter-day practice with the Schmidt patents, and also with the Swindon and the Robinson variants, is in favour of the smoke-tube type; on the other hand, the Phœnix superheater, first put on the market in 1910, is of the smokebox variety, as is also the Vauclain, so much favoured in America.

After considerable controversy it is now generally held that the provision of superheating apparatus is unjustified unless the superheat is carried to a high degree, such as 300° F., bringing the maximum steam temperature

to between 650° and 750° F. For this reason the smokebox superheater or steam drier has fallen out of favour during recent years.

May superheating be economically applied to various types of locomotives irrespective of the service for which they are intended? We see arrangements of the kind fitted to engines which must often in the ordinary course of things work trains with frequent stops, and special apparatus, such as that introduced by Sir Henry Fowler on the Midland Railway, provided to deal with such contingencies. Earlier views on the matter were that superheating could not be expected to give good results in circumstances of the kind, and it may well be that this is yet another point upon which further experience is necessary.

Utilization of Energy.—Having now traced the chief points in the development of the modern locomotive boiler, it remains to consider how the increased motive power so obtained has been utilized. For, important though the generation of steam may be, there must be a proper correlation between boiler capacity, cylinder capacity, and driving-wheel diameter and arrangement if results at all adequate are to be obtained. Over fifty years ago engines equipped with but a pair of cylinders of 18 in. diameter and 24 in. stroke were given boilers of over 2000 sq. ft. heating surface supplied mainly by small boiler barrels closely packed with tubes, and it is only comparatively recently that the importance of securing as large a steam space as possible in the boiler has been recognized, Mr. McIntosh on the Caledonian leading the way in 1895 with his first " Dunalastairs ". From that date there has been a fairly consistent tendency to provide boilers of such dimensions as to ensure an adequate steam space in addition to the requisite number and size of tubes to secure a given heating surface.

Widely differing Practice as to Cylinder and Wheel Dimensions and Arrangement.—With respect to cylinder and wheel dimensions and arrangement the case is far different, and practice is widely distinct as between one designer and another, and indeed often varies considerably in locomotives built for practically identical duty by the same designer. There is therefore a considerable range in the ratios of heating surface to cylinder capacity, and little approach has been made to the desirable goal of standardization of types. Not that standardization is by any means neglected—in fact several British designers have made great strides in this direction in recent years—but it has taken the form rather of standardization of *parts*, often of the boiler in its entirety. Mr. Churchward, for instance—and he is not alone in the practice—uses the same boiler for several varying types of engines. Even in such exceptional design as his first British " Pacific ", the engine and tender bogies are identical except as to wheelbase, and the details are standard with the bogies and pony trucks given his 4—4—0, 4—4—2, 4—6—0, 2—8—0, 2—6—2 tank and 4—4—2 tank classes. In addition, the coupled wheels and axles are interchangeable with those of the preceding " Star " class, as are also the connecting rods, valves, valve gear, and reversing gear. Moreover, the axleboxes and spring gear are interchangeable with all the classes mentioned,

and the trailing wheels and axle with the 4—4—2 tank and 2—6—2 tank classes. It is, however, almost impossible to imagine British locomotive design approaching that high degree of type standardization which obtained in France when the de Glehn system became so widespread in adoption, nor the lesser degree of standardization introduced by the Indian Government in more recent years, although the tendency is distinctly towards reduction in the number of types on one and the same railway.

The wide divergence of practice with respect to the number, size, and placing of cylinders and the diameter and disposition of wheels above spoken of renders it desirable that these questions should be dealt with in conjunction with the several locomotive types involved, but it would be well that some space should here be devoted to the more recent compound practice in Britain.

Compounding.—It is not proposed to enter in any way into the controversy which has for so many years raged on the respective merits of the two principles of steam expansion for locomotives. To do so adequately and with any measure of justice to the respective theories would demand considerable space, and would of necessity be little more than a recital of well-worn history. Certain salient facts may, however, be set forth with advantage.

Webb's Compounds and their Fate.—So far as actual British practice is concerned, compounding received a serious blow when Mr. F. W. Webb's influence was removed. It is true that his practice did not commend itself to many of the friends of compounding, but nevertheless for many years Mr. Webb stood almost, if not indeed at times quite, alone amongst British engineers as a builder of compound engines. When he retired at the end of 1902 the only compound locomotives, other than his own numerous three-cylinder and four-cylinder classes, running in the British Isles were such of the Worsdell-von Borries two-cylinder compounds on the North-Eastern as had not then been converted, a few similar engines on two of the Irish lines, two Smith three-cylinder compounds on the Midland and one on the North-Eastern, and a Lancashire and Yorkshire engine compounded much on the lines of his own four-cylinder system. His successor, Mr. George Whale, soon showed the trend of his own mind, and created something in the nature of a sensation by the drastic steps he took with respect to the Webb compounds. Some of them, such as the three-cylinder express classes, he sent to the scrap heap; others, such as the three- and four-cylinder goods engines, he converted to two-cylinder simples or " semi-compounds ". In fact, in a few months he swept away the compound tradition on the North-Western, and in doing so inflicted what has surely since proved to be a fatal blow at the principle of double expansion for locomotives in this country.

Revival of British Interest in Compounding.—By a strange coincidence, the year which marked the virtual retirement of Mr. Webb also witnessed a revival of interest in compounding on certain British lines other than the London and North-Western. This renewed attention to the claims of compounding was brought about almost entirely by the success of the du Bousquet-de Glehn compounds on the Nord Railway in France. One

result of this awakened interest was a somewhat extensive use of the compound system on the Midland, together with further experiments with Smith compounds on the North-Eastern and Great Central; another was the trials with three French-built de Glehn compounds on the Great Western and with two compounds built on de Glehn lines for the Great Northern. This renewed interest, however, has proved entirely evanescent.

Smith's Three-cylinder Compound System on the Midland.—Before his retirement at the close of 1903 Mr. Johnson had built for the Midland five engines (Nos. 2631–5) compounded on the Smith three-cylinder system with two outside low-pressure 21-inch cylinders and a 19-inch high-pressure cylinder between the frames, thus reversing Mr. Webb's three-cylinder practice. The steam admission was so arranged that the locomotive could be worked at will as a compound, as a "semi-compound", and even, if thought desirable, as a simple engine. All three cylinders drove on the leading coupled axle. The reducing valve arrangement, however, gave considerable trouble, and Mr. Deeley, on taking office, soon substituted an arrangement of his own, which he also fitted to the further compounds built by him for this line.

Smith's Compounds on the North-Eastern and Great Central.—The first North-Eastern and the four Smith compounds on the Great Central had the same arrangement for live-steam admission as in the case of the Midland compounds, but the de Glehn practice was followed in making the low-pressure cylinders drive on the trailing and the high-pressure cylinders drive on the leading coupled axle. The later North-Eastern compounds are on Smith's four-cylinder plan, with two $14\frac{1}{4}$-in. high-pressure cylinders, and two 22-in. low-pressure cylinders, all four driving the front coupled wheels. Both systems certainly seemed to give great satisfaction, and a more extended use might well have been looked for on the lines employing them but for the intervention of superheating.

Lancashire and Yorkshire Compounds.—The first essay in compounding on the Lancashire and Yorkshire Railway was with a four-coupled engine which in 1901 was given two $12\frac{5}{8}$-in. high-pressure and two $21\frac{5}{8}$-in. low-pressure cylinders. The experiment was not followed up, but about six years later Mr. Hughes put on the road a class of four-cylinder balanced compound 0—8—0 mineral engines with $15\frac{1}{2}$-in.-by-26-in. high-pressure and 22-in.-by-26-in. low-pressure cylinders, all operating the third pair of coupled wheels. The usual provision is made for admitting boiler steam when required to the low-pressure steam chests.

Dean's Compounds on the Great Western.—The first trials of the compound system on the Great Western took place very many years ago, when Mr. Dean built two four-cylinder tandem compounds, one for the broad and one for the narrow gauge. These engines were constantly in trouble through the absence of any provision for getting the water away from the cylinders on the inside. Broken piston heads were consequently matters of common occurrence, and to save the expense of re-designing the cylinders the trials were abandoned and Mr. Dean reverted to the simple engine.

Churchward's Trials of Compounds.—In July, 1904, Mr. Churchward commenced his comparative trials with an imported de Glehn compound and a Swindon-built high-pressure simple 4—6—0 engine, and in the following year tried two more of these French engines of higher boiler power, the 4—6—0 engine " Albion " having in the meantime been converted into an " Atlantic ", the first of that type of British build tried on the Great Western, but afterwards (1907) re-converted to the 4—6—0 type.

Since these trials three significant points of Great Western practice have made themselves apparent, namely:

1. No more compounds have been placed upon the road.
2. Mr. Churchward's later express engines have been of the four-cylinder *simple* type.
3. He has built no more " Atlantics ".

Ivatt's Four-cylinder Compounds.—Mr. Ivatt gave the Great Northern its first compound engine early in 1905, when he fitted one of his standard " Atlantics " as a four-cylinder compound much on the lines of the de Glehn arrangement. Later in the year a balanced four-cylinder compound more closely approximating to the de Glehn types was supplied by the Vulcan Foundry Company, of Newton-le-Willows. A more recent development was the four-cylinder " Atlantic " No. 1421, which has several interesting points of difference from his earlier Doncaster-built compound. For example, Walschaerts' valve gear operates the low-pressure as well as the high-pressure cylinders; the leading coupled crank axle is of his patent built-up balanced type; and the smokebox is recessed instead of being advanced in front of the chimney, resulting in a reduction of total heating surface from 2500 sq. ft. to 2351·8 sq. ft.

The Prospects of Compounding in Britain.—In the face of what has been done in Britain in compounding, it seems difficult to maintain, as some do, that the compound has never been tried sufficiently to justify the neglect the principle has hitherto met with at the hands of the large majority of British engineers. It would be easy to give the case for and against the compound principle *per se*; it has been done over and over again. But what would it avail? The tree must be judged by its fruits. It is now hardly seriously contended by anyone that there did not exist in the Webb and Worsdell compound systems such inherent defects as to justify some part at least of the criticisms passed upon them in this country. There is the fact, nevertheless, that the Worsdell-von Borries engines at least seem to maintain a good name elsewhere. Again, what explains the failure of the de Glehn compounds, with their splendid record in Europe, to convince a British locomotive engineer pre-eminent in the search after truth? At one time it appeared that it was to be left to the late Mr. Smith to re-establish compounding in this country to a more respectable extent; but in view of the recent decided move on the part of several of our leading locomotive designers towards the four-cylinder high-pressure engine it seems doubtful whether compounding will ever make much further headway.

The " personal equation " is strong in matters of locomotive design and construction, and there is little doubt that with few exceptions present-day British opinion is still wedded to the single-expansion system.

The Express Engine of the Future.—So far as express engine design is concerned, recent developments would seem to indicate that future practice will rather be in the direction of four-cylinder simple engines, with large fireboxes and boilers supplied with superheating apparatus, carried on six-coupled wheels and a leading axle or bogie: one finds it difficult to believe that the " Pacific " (4—6—2) type will ever be multiplied to any extent in this country, or that we shall ever witness the introduction of any of the American mastodon locomotives.

The question, indeed, seems to arise, as it has arisen in America, whether we have not after all proceeded too far in the construction of enormous locomotive machines. Of course, if work can be found to adequately extend these latter-day monsters, their multiplication may be justified; but they are costly machines to build, they are costly to maintain, and there is the undoubted fact that much less powerful engines are doing every day, with pronounced success, much of the work that is often offered to the mammoths. Equally, of course, if allotted loads and demanded speeds continue to increase, even to a slight extent, it will be necessary to relegate the less powerful of the four-coupled type, if not indeed the larger machines of the same class, to the less important services. It is perhaps flying in the teeth of all accepted railway economic principles to imagine for a moment the possibility of reverting to light loads and locomotives, and, of course, duplicating the present heavy trains. That the enlargement of the locomotive to meet growing demands cannot go on indefinitely is evident; in fact, as it is, more than one road in the country would have very serious expenditure to face before the larger, longer, heavier machines now found on the great trunk railways could be adopted, and with these companies it would in some cases be a grave question whether it would not be better policy to decrease either the load or the rate of speed, or both. Those persons who are not intimately acquainted with railway economics are apt to forget that large locomotives are not merely in themselves more expensive machines than smaller ones, but that their adoption entails heavy outlay on the reconstruction and maintenance of bridge and permanent way, turntables, &c.

Valve Gear.—A word or two may perhaps here be inserted with respect to the motion. So far as Britain is concerned, the Stephenson link motion has reigned supreme, although Joy's radial gear has had some vogue and the Allan straight-link motion has also been in use. With the advent of the large modern boiler, however, accompanied as it was by the practice of driving off axles other than the leading, came the much more extended use of the outside position for the cylinders, and this in turn has led to a growing disposition to employ the Walschaerts' gear. This gear is now usually adopted by the principal locomotive designers in this country, and it is easy to foresee a much extended employment in the near future. The

Walschaerts' gear, also known as the Heusinger von Waldegg, invented in 1844 by Egide Walschaerts, was first brought prominently into notice by reason of its introduction on the Belgian railways. Although it made its appearance in this country in 1882, and in 1890 was utilized in the Worsdell–von Borries two-cylinder compounds for the Belfast and Northern Counties line, very little was heard of it until the purchase of the Great Western de Glehn compounds and the advent of the rail motor-car. There is now every reason to believe that the gear will soon be adopted as standard practice with the larger types of engines quite irrespective of whether the cylinders are placed inside or outside the framing.

Walschaerts' gear has always been popular, and for many years practically standard on most of the Continental railways. More perfect steam distribution in all degrees of expansion, a saving of fully one-third of the weight of moving parts, as compared with the Stephenson link motion, reduction of friction, and the easy adaptation, especially to engines having outside cylinders and valves, are among the advantages.

Trials made in 1901–2 on several lines with the Marshall radial gear, for which was claimed the advantages of a steam distribution similar to that of the Corliss gear, did not result in further experiments, and the battle must be left to the Stephenson and Walschaerts' forms.

CHAPTER II

Modern Locomotive Types

In reviewing the chief locomotive types in use in the British Isles it is proposed to deal with them as concisely as possible under the heads comprised in Table V (p. 40).

This table by no means exhausts the list of existing types. For instance, amongst the passenger engines useful work is still being performed by such of the 2—2—2 and the 4—2—2 types of "single" engines (that is, those with a single pair of driving wheels), the Stroudley type of 0—4—2 engines, and locomotives of the reverse wheel arrangement (2—4—0) as still survive. The singles and the Stroudleys are simply running out their lives. The 2—4—0 engines on the London and North-Western, the Great Eastern, and the North Staffordshire, although serviceable, are not at all likely to be perpetuated. Again, amongst the many types of useful tank engines not included may be mentioned the 4—4—0, used on the Metropolitan and North London and to some extent in Scotland, the 4—4—4 tanks running on the Midland and South-Western Junction and the Wirral lines, and the North British 2—4—4 tanks, these forming but a very small proportion of the whole. There have been constructed, moreover, during the past twenty years, several experimental engines possessing features of very great interest, which, like the "Great Bear", have been the sole

TABLE V

Wheel Arrangement.	Passenger Tender Engines.	Tank Engines—Passenger and Goods.	Goods Tender Engines.
4—4—0	Four-coupled bogie.		
4—4—2	"Atlantic."	"Atlantic."	
4—6—0	Six-coupled bogie.	Six-coupled bogie.	Six-coupled bogie.
0—4—4		Four-coupled trailing bogie.	
2—4—2		Four-coupled double-ender.	
0—6—0		Six-coupled.	Six-coupled.
0—6—2		Six-coupled radial.	
0—6—4		Six-coupled trailing bogie.	
2—6—2		Six-coupled double-ender.	
4—6—2	"Pacific."	"Pacific."	
4—6—4		"Baltic."	
2—6—0			"Mogul."
0—8—0		Eight-coupled.	Eight-coupled.
0—8—2		Eight-coupled radial.	
2—8—0		"Consolidation."	"Consolidation."
0—8—4		Eight-coupled banking.	
4—8—0		Eight-coupled banking.	

representatives of their type. Such were Mr. James Holden's three-cylinder simple decapod (0—10—0) tank engine and the Reid-Ramsay-turbo-electric-locomotive.

Passenger Tender Engines: The "Singles".—It is impossible to pass to the consideration of the more modern types of passenger engines without expressing a word of regret at the supersession and apparently inevitable extinction of the "single-wheelers", which by reason of the minimum amount of friction involved in the delivery of power to the rails through a single pair of driving wheels form the ideal design for a locomotive. Their powers as regards running at speed with the lighter loads of their day are undoubted—in fact the speed reputation enjoyed by more than one of our leading lines to-day was entirely built up on their performances (sometimes, by the way, with loads of respectable dimensions even for these days); but the absolute necessity of getting sharply into a "stride" on starting with heavy loads—of maintaining a comparatively high rate of speed when surmounting "banks"—the deficiency of adhesion in the singles—the need of larger boilers than could be employed with engines of the kind—the impossibility of utilizing to any advantage in such engines the increased steam power available, even if such boilers could be provided—these considerations were the doom of the single-drivers. No such engines, except a very few re-builds, have been turned out of shops since 1901, and it is very questionable whether any further engines of the type will ever be built, although those still in existence, are doing excellent service where opportunity is afforded of showing themselves to any advantage. Indeed,

looking to the frequency with which one notices heavy engines of the 4—4—0, 4—4—2, and 4—6—0 types running over roads presenting no great difficulties in the way of adverse gradients, with comparatively light loads—loads that many of the existing singles can in the circumstances, and often do, haul with ease, it would seem that the death of the type might be delayed with advantage for some years to come.

The Four-coupled Type.—As it is, speaking generally, the great bulk of the work, taking it as it comes, is still done by the friendly competitor of the singles—the 4—4—0 type. In fact these engines are the standard practice for express work on several important railway systems, and do the largest share on many important services on systems which have of late built largely to the 4—4—2 and 4—6—0 arrangements. In point of numbers the 4—4—0 type is still in excess and, so far as the smaller lines at least are concerned, meets all requirements, present or prospective. The following table of the fifteen principal British companies shows the date of proceeding to 4—4—2 and 4—6—0 tender engines. It is necessary to remember in this connection that the six-coupled engines, introduced by Mr. D. Jones on the Highland line in 1894, were primarily intended for heavy goods traffic.

TABLE VI

Company.	4—4—2	4—6—0	Company.	4—4—2	4—6—0
Great Eastern	—	1912	London and South-Western ...	—	1905
Great Northern	1898	—	London Brighton and S. Coast	1905	—
North-Eastern	1904	1899	South-Eastern and Chatham ...	—	—
Great Central	1903	1902	North British	1906	1908
Midland	—	—	Caledonian	—	1902
London and North-Western	—	1903	Glasgow and South-Western ...	—	1903
Lancashire and Yorkshire ...	1899	1908	Highland...	—	1894
Great Western	1905	1902			

It will be seen that the Midland and the South-Eastern and Chatham systems rely entirely on the " four-coupled " (4—4—0) class to work their long-distance traffic, supplemented on the Midland by a few " singles " and on the South-Eastern and Chatham Railway by Mr. Maunsell's 2—6—0 engines. Again, the " Atlantic " type is not found on the Great Eastern, the London and North-Western, or the London and South-Western; it is not seen in Ireland nor in Scotland, except on the North British line, and it may be considered doubtful whether railways which have not hitherto built the 4—4—2 engines will ever do so, it being felt that when adopting the larger boilers, with consequent increase in weight, advantage should be taken of the opportunity to secure the greater adhesion accruing from coupling up the rear pair of wheels. It would therefore appear that the express work of the future is likely to be in great measure shared between engines with four-coupled and those with six-coupled wheels, without additional carrying wheels behind the coupled axles.

Diversity in Design.—Among engines of the 4—4—0 type on the various lines the greatest diversity of design exists, not only between engines on different railways, but also between those on one and the same line. This is due in the main to that entire absence of any attempt at standardization which has in the past been so characteristic of British locomotive engineering. It was long an article of faith with our locomotive engineers that originality in design was of great importance, and consequently under each succeeding regime the various types of locomotives owned by any one company became increased in number. But this is not all. It was equally the practice to build only, as it were, to meet the circumstances of the hour, and little reserve of power was given the locomotives. When the growing traffic called for increased tractive power this was as a rule sought in " ringing the changes " on cylinder dimensions and wheel diameters rather than in increased steam-raising ability—indeed, instances are not unknown of smaller boilers being provided. Then, again, an engineer, in order to meet the more pressing demands of a particular class of traffic or to grapple more effectually with special features in the profile of some portion of the road, would build classes of engines varying largely in details from those of the same type previously designed by him. Moreover, British locomotives have always been built " to last ". Excellence of material and workmanship alike gave them a surprisingly long life even in their original form, and by a judicious system of repairs and renewal of parts their existence has often been prolonged to an extent which has not always been without its disadvantages. Thus, while what was left of the grand old veterans, rejuvenated by extensive overhauls, repairs, and re-buildings, " lagged superfluous on the stage ", other classes of little or no greater power were being multiplied, until on most lines the locomotive stock consisted of a heterogeneous collection of engines of much the same power, some ostensibly over forty years old. There are, however, undoubted signs of a reaction, which may in course of time result in the attainment of a large measure of standardization. It is becoming more and more recognized that large economies may often result from even that amount of uniformity of design which we now see on some lines as regards boilers, cylinders, running gear, and other important parts.

The wide differences which still exist render it almost impossible to deal with them in detail without going to great length. It will, perhaps, suffice to show, as in Table VII, a few of the chief particulars of British express locomotives, mainly of the 4—4—0 classes, reported to the International Railway Congress of 1895, contrasted with similar information respecting representative engines of the 4—4—0 type owned by the same companies to-day.

The " pitch " of the boiler in 1895 varied from 6 ft. 7 in. on the Furness to 7 ft. 11 in. on the North-Eastern; now boilers with their centre lines 8 ft. to 8 ft. 6 in. above the rails are found on such lines as the Great Eastern, the South-Eastern, and the Brighton, carried over four-coupled wheels of the same diameter as formerly used with the smaller boilers.

Ignoring the compounds, the only engines shown in the table with which outside cylinders are associated are the single-drivers on the Great Northern and the earlier types of 4—4—0 engines on the London and South-Western and the Highland lines; the later engines on these railways all have the inside cylinders wherever possible. However, one result of the employment of the large boilers in the 4—4—2 and 4—6—0 classes has been the much more frequent use of the outside position for the cylinders which has already been referred to.

The table, of course, makes no pretence to be exhaustive. It may, however, be accepted as on the whole fairly representative of British practice in locomotives of the type with which so much good work has hitherto been done.

Widely varying Ratios.—An examination of the figures in Table VII will be found to disclose wide differences in ratios, such as firebox heating surface to tube heating surface, grate area to total heating surface, total heating surface to cylinder capacity, tractive force to adhesion, weight, &c. The thoughtful student will find much of interest in making some of these comparisons. He may, for instance, contrast Mr. Worsdell's practice in providing a boiler having 1527 sq. ft. of heating surface, with valves set to blow off at 200 lb. pressure, to supply steam to 19-in.-by-26-in. cylinders, with the 2010 sq. ft. of heating surface and the 175 lb. pressure given by Mr. Whale to his "Precursor" class for cylinders of the same size, the driving-wheel diameter being practically the same in both cases.

Influence of Local Conditions on Design.—This diversity in practice is not, however, so much the result of personal predilection as an endeavour to meet in the best possible way the local exigencies with which each designer is faced. In some cases much of the heavier traffic over long distances was already being dealt with by engines of more powerful type at the time the later 4—4—0 engines shown in the table were built, as for instance on the Great Northern, Great Central, Great Western, North-Eastern, and Caledonian lines. On the other hand, some designers have to rest content with the limited possibilities of the 4—4—0 type for even their heaviest traffic. More than one engineer in the country has at times found himself debarred from building engines of the more powerful types by reason of limitations imposed by the permanent-way engineer in respect of weight or wheelbase. It must ever be borne in mind in this connection that our railways as originally laid down were not intended to meet the conditions of the present day. It is, indeed, only at enormous expenditure that the adoption of larger locomotives has been rendered possible on some lines, and, as already indicated, such expenditure is probably out of the question with others.

To see what good work can be done with 4—4—0 engines in the teeth of difficulties and limitations of no mean order one need only glance at the performances of such classes as the "Claud Hamiltons" on the Great Eastern, the "City" and "County" classes on the Great Western, the "Precursor" classes on the London and North-Western, the "mixed traffic" engines on the London and South-Western, or Mr. Wainwright's

TABLE VII.—TYPICAL ENGINES OF 4—4—0 TYPE

Railway.	Boiler. Length of Barrel.	Boiler. Minimum Outside Diameter.	Pressure.	Grate Area.	Heating Surface. Tubes.	Heating Surface. Firebox.	Heating Surface. Total.	Cylinders. Diameter.	Cylinders. Stroke.	Diameter of Driving Wheels.	Weight in Working Order. On Coupled Wheels.	Weight in Working Order. Total.	
	ft. in.	ft. in.	lb. per sq. in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	in.	in.	ft. in.	tons cwt.	tons cwt.	
Great Eastern ...	10 0	4 3	140(*a*)	18	1116.18	100.9	1217.08	18	24	7 0	27 12	42 0	2—4—0
	11 9	4 8	180	21.6	1588.88	117.70	1706.58	19	26	7 0	34 9	51 14	——
Great Northern ...	11 5	4 0	170	17.75	936	109	1045	18	28	8 1½	18 0	44 19	4—2—2
	10 1	4 9	175	20.8	1129.9	119.9	1249.8	17½	26	6 7½	30 18	47 6	——
North Eastern ...	11 6	4 4	160	19.6	1220	121	1341	19	26	7 1¼	34 4	51 4	——
	11 6½	5 6	225	27	1579	158	1737	19	26	6 10	42 0	59 10	——
Great Central ...	10 8	4 2	160	18.85	1179	99	1278	18	26	6 9	32 1	46 0	——
	11 6	4 9	180	21	1284	130	1378	18½	26	6 9	35 12	53 1	——
	12 3	5 0	180	26	1388	155	1543	20	26	6 9	—	—	New "Director" class.
Midland	10 6	4 1	160	17.5	1151	110.2	1261.2	18	26	7 0	28 3	42 15	——
	11 7	4 8	195	26	1448	150	1598	19 (one) 21 (two)	26	7 0	38 3	58 9	3-cyl comp.
London and North-Western	18 6(*b*)	4 2	175	20.5	1346 (*b*)39·1	120.6	1505.7	15 (one) 30 (two)	24	7 1	31 0	52 2	3-cyl. comp. 2—4—2
	11 9¾	5 2	175	22.4	1848.4	161.5	2009.9	19	26	6 6	38 0	59 15	——
Lanc. and Yorks. ...	10 7⅜	4 2	160 175	18.75	1108.73	107.68	1216.41	18	26	7 3	31 0	44 16	Joy's gear.
Great Western ...	10 6	4 2½	150	20.8	1206.7	121.4	1328.1	18	24	7 1	15 0	35 2	2—2—2
	11 6	5 4⅚	210	17.85	1803.27	130.75	1934.02	18	26	6 8½	35 10	56 14(*c*)	——
London and South-Western	11 0	4 4	175	18	1245.6	122.16	1367.76	19	26	7 1	30 6	48 14	——
	10 6	5 0	175	24	1222	163 165 (water tubes)	1550	19½	26	6 7	37 2	53 19	——
London Brighton and South Coast	10 2	4 4	150	20.65	1378.2	113.9	1492.1	18¾	26	6 6	24 18	38 14	4—2—0
	10 10½	4 10	180	24	1509	126	1635	19	26	6 9	33 0	49 0	——
South-Eastern and Chatham... ...	10 4½	4 4	150	16.78	880.76	103.5	984.26	19	26	7 0	28 18	42 10	S. E. R.
	10 5	4 2⅜	150	17.0	1000.2	110	1110.2	18	26	6 6	28 18	42 9	L. C. & D. R.
	11 1	4 9	180	21.15	1396	136	1532	19¼	26	6 6	34 18	52 5	S. E. & C. R.
North Staffordshire	——	4 6	175	21	1092	133	1225	18½	26	6 0	32 0	48 0	First 4—4—0
Hull and Barnsley	11 4⅝	5 0 (max.)	170	19.6	——	——	1407	18½	26	6 6	36 2	55 2	First 4—4—0

TABLE VII (*Continued*)

Railway.	Boiler.		Pressure.	Grate Area.	Heating Surface.			Cylinders.		Diameter of Driving Wheels.	Weight in Working Order.				
	Length of Barrel.	Minimum Outside Diameter			Tubes.	Firebox.	Total.	Diameter.	Stroke.		On Coupled Wheels.		Total.		
	ft. in.	ft. in.	lb. per sq. in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	in.	in.	ft. in.	tons cwt.		tons cwt.		
Furness	10 4	4 1	140	14.3	955	86	1041	17	24	5 $7\frac{1}{2}$	25 4		36 17		——
	10 $8\frac{3}{8}$	4 4	160	18	1159	111.5	1270.5	18	26	6 6	27 19		43 0		——
North British ...	10 $3\frac{1}{2}$	4 $5\frac{1}{8}$	150	20	1144	118	1262	18	26	6 6	30 19		46 0		——
	—	—	175	—	1620	140	1760	19	26	6 0	34 0		52 0		——
Caledonian	10 $3\frac{1}{2}$	4 $5\frac{1}{2}$	160	19.5	1071.5	112.6	1184.1	18	26	6 6	30 12		45 6		——
	11 1	5 $0\frac{1}{2}$	180	23	1462.8	138	1600.2	19	26	6 6	34 13		51 14		——
Glasgow and South-Western	10 $3\frac{1}{2}$	4 $5\frac{1}{8}$	150	18	1094	111	1205	$18\frac{1}{4}$	26	6 $9\frac{1}{2}$	30 17		45 1		——
	—	—	160	22	1315	119	1434	$18\frac{1}{4}$	26	6 $9\frac{1}{2}$	33 0		50 10		——
Highland	9 $9\frac{1}{2}$	4 5	160	18.8	1127	115	1242	18	24	6 $3\frac{1}{2}$	29 10		45 0		Allan gear.
	9 $9\frac{1}{2}$	4 5	175	20.75	1176	119	1295	19	24	6 3	31 14		49 0		——
	—	—	160	—	—	—	—	20	26	6 3	—		98 8		——
Great North of Scotland	10 6	4 4	165	18	1093.5	113.5	1207	18	26	6 1	29 11		43 18		——
											30 0		44 18		——
Great Southern and Western	9 $9\frac{1}{4}$	4 3	150	18.8	938	112.4	1050.4	18	24	6 $7\frac{1}{2}$	25 15		39 6		——
	10 $3\frac{3}{4}$	5 $6\frac{5}{8}$ / 5 $0\frac{1}{2}$	160	23	1366	145	1511	$18\frac{1}{2}$	26	6 7	36 0		49 15		Coned boiler.
Belfast and Northern Counties	10 0	4 1	170	14.5	898	82	980	23 $\frac{1}{2}$ (one) / 16 (one)	24	6 0	24 19		36 14		2—4—0
	10 $7\frac{13}{16}$	4 4	180	18.25	1046.93	106.7	1153.63	18 (one) / 26 (one)	24	6 0 / 7 0	30 10		48 0		2-cyl. comp. (*d*)
Great Northern (Ireland)	10 3	4 3	150	16.5	1012	102	1114	17	24	6 7	27 0		39 0		——
	11 0	4 6	175	22.14	1397.96	133.34	1531.3	$18\frac{1}{2}$	26	6 7	33 8		49 10		——
Cambrian	10 7	4 5	170	20.5	1166	117	1283	$18\frac{1}{2}$	26	6 0	29 13		45 5		——

(*a*) Afterwards raised to 160 lb. Many engines since rebuilt with boilers carrying working pressure of 180 lb., and provided with Belpaire fireboxes. Some of these rebuilds have been given leading bogies, and are consequently now of the 4—4—0 type.

(*b*) 2 ft. $8\frac{1}{2}$ in. combustion chamber, placed in barrel 5 ft. 10 in. from firebox-tube plate, gave 39.1 sq. ft. of heating surface. Indirect curved link motion for high-pressure slide valves; single loose eccentric for low pressure.

(*c*) Re-built "Badminton" class, exceptionally provided with round-topped boilers, fitted with *domes*.

(*d*) Worsdell compounds. Walschaert's valve gear. Railway now part of Midland system, being known as Midland Railway Northern Section).

four-coupled bogie express engines on the South-Eastern and Chatham lines.

A Typical 4—4—0 Line.—Until the advent of the 4—6—0 engines the bulk of the express duty on the Great Eastern Railway was carried on by engines of the 4—4—0 type constructed since 1900, assisted by about 60 of the older 2—4—0 re-built with larger (Belpaire) boilers and leading bogies. The lighter and branch work is to a large extent taken by the remaining engines of the 2—4—0 type re-built with Belpaire boilers but with no bogie, and by a very useful 2—4—0 type of " mixed-traffic " engines. The chief particulars of these engines are shown in Table VIII.

Great Western " City " and " County " Classes.—The typical Great Western 4—4—0 engines are the " City " class with *inside* cylinders and the " County " class with *outside* cylinders, both having the same pattern of coned boiler. Some of the best work on that system of fine locomotive performance has been done by these two classes, the leading dimensions of which are as shown in Table IX.

It will be noticed that in building the " County " class Mr. Churchward placed the cylinders outside the frames and, as was customary with him when employing outside cylinders, he gave a piston stroke of 30 in.—a practice in which he stood alone amongst modern British locomotive engineers.

Four-cylinder Simple Engines.—It has been remarked that there has of late been a tendency to employ four high-pressure cylinders. The principle is not new. So far back as 1861 John Haswell built at Vienna an engine of no great power with four cylinders $10\frac{7}{8}$ in. diameter by $24\frac{7}{8}$ in. stroke, placed two on each side of the engine outside the framing and one above the other. This engine was of the 4—2—0 type. Its boiler was long but inadequate for supplying steam to the cylinders. Much the same criticism could be passed on the 4—4—0 engine with which Mr. Manson inaugurated the four-cylinder simple type in this country in 1897, inasmuch as to supply boiler steam to two cylinders of $14\frac{1}{2}$ in. diameter and two of $12\frac{1}{2}$ in. diameter, with a piston stroke of 26 in., he provided a boiler only 10 ft. 6 in. long and of 4 ft. 3 in. diameter, with tubes giving a heating surface of 1094 sq. ft., to which was added the 111 sq. ft. of heating surface afforded by a 6-ft.-2.in.-by-4-ft. firebox with 18 ft. of grate, the pressure used being moreover no more than 165 lb. to the square inch. Mr. Drummond, on the London and South-Western, in his first four-cylinder engine built in the same year, gave much more boiler power for supplying his four 14-in.-by-26-in. cylinders. In this class the outside cylinders, placed farther back than the inside pair, drove on the trailing wheels, and the inside cylinders drove the leading pair of wheels behind the bogie. The driving wheels were not coupled together, and thus the engine, like Mr. Webb's three-cylinder compounds, was rather 4—2—2—0 than 4—4—0 in type. This latter practice was not, however, extended even by Mr. Drummond himself; but, although both the Glasgow and South-Western engine and Mr. Ivatt's four-cylinder " Atlantic ", which followed in 1902, were arranged for all four cylinders to drive on the leading coupled axle, later practice has been

ENGINES

Railway.	Γ	Working Pressure.	Cylinders.		Diameter of Driving Wheels.		Weight in Working Order.				Wheel Base.				Weight per Foot Run.			
			Diam.	Stroke.			On Driving Wheels.		Total.		Driving.		Total.		Driving Base.		Total Base.	
		lb. per sq. in.	in.	in.	ft.	in.	tons	cwt.	tons	cwt.	ft.	in.	ft.	in.	tons	cwt.	tons	cwt.
lasgow and South-Western	1	165	two inside, 14½ / two outside, 12½	26 / 24	6	9½	31	14	48	10	8	9	21	8	3	12	2	5
ondon and South-Western	1	175	14	26	6	7	—		54	11	11	0	—		—		—	
ondon and South-Western	1 (re	175	14	26	6	7	—		60	1	11	0	—		—		—	
ondon and South-Western	1	175	16	24	6	0	51	10	73	0	13	4	26	5	3	17	2	15
ondon and South-Western	1	175	16½	26	6	0	52	10	74	0	13	4	26	10	3	19	2	15
reat Northern ...	1	175	15	20	6	7½	32	0	60	0	—		26	9	—		2	5
reat Western ...	1	225	14¼	26	6	8½	39	12	74	10	7	0	27	9	5	13	2	14
reat Western ...	1	225	14¼	26	6	8½	55	8	75	12	14	9	27	3	3	15	2	15
reat Western ...	19	225	15	26	6	8½	61	7	97	5	14	0	34	6	4	8	2	16
ancs. and Yorks.	1	180	16	26	6	3	59	1	77	1	13	5	25	2	4	8	3	1

[*To face p. 46 of Vol. I.*

TABLE X.—PIONEER FOUR-CYLINDER SIMPLE ENGINES

Railway.	Date.	Type.	Boiler Barrel.			Firebox.				Grate Area.	Heating Surface.					Working Pressure.	Cylinders.		Diameter of Driving Wheels	Weight in Working Order.		Wheel Base.		Weight per Foot Run.	
			Length.	Minimum Diameter Outside	Pitch.	Length at Base.	Width at Base.	Depth.			Fire Tubes.	Firebox Water Tubes.	Superheater Tubes.	Firebox.	Total.		Diam	Stroke.		On Driving Wheels.	Total.	Driving.	Total.	Driving Base	Total Base.
								Front.	Back.																
			ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	lb. per sq. in.	in.	in.	ft. in.	tons cwt.	tons cwt.	ft. in.	ft. in.	tons cwt.	tons cwt.
Glasgow and South-Western	1897	4—4—0	10 6	4 2	7 6	5 6¾	3 4	5 11	5 4	18	1095	—	—	111	1206	165	two inside, 14½ | 26; two outside, 12½ | 24		6 9½	31 14	48 10	8 9	21 8	3 12	2 5
London and South-Western	1897	4—4—0 (4-2-2-0)	12 0	4 5⅛	7 9	8 4 (casing)	4 0½ (casing)	—	—	27.4	1344.4	190	—	156	1690.4	175	14	26	6 7	—	54 11	11 0	—	—	—
London and South-Western	1905 (rebuilt)	4—4—0 (4-2-2-0)	12 0	4 10⅝	—	8 4 (casing)	4 0½ (casing)	—	—	27.4	1392	195	—	173	1760	175	14	26	6 7	—	60 1	11 0	—	—	—
London and South-Western	1905	4—6—0	13 9	5 7⅛	9 0	8 4¾	—	6 1¼	5 10¼	31.5	2210	357	—	160	2727	175	16	24	6 0	51 10	73 0	13 4	26 5	3 17	2 15
London and South-Western	1907	4—6—0	13 9	5 8¾	9 0	8 4⅜	—	6 1¼	5 10¼	31.5	2210	357	—	160	2727	175	16½	26	6 0	52 10	74 0	13 4	26 10	3 19	2 15
Great Northern ...	1902	4—4—2	14 0 (between tube plates)	4 8	—	8 4 (casing)	4 0½ (casing)	—	—	24.5	1162.75	—	—	140.25	1303	175	15	20	6 7½	32 0	60 0	—	26 9	—	2 5
Great Western ...	1906	4—4—2	14 10	5 6 | 4 10⅞ (coned)	9 0	8 2 7/16	3 2⅝	—	—	27.07	1988.65	—	—	154.26	2142.91	225	14½	26	6 8½	39 12	74 10	7 0	27 9	5 13	2 14
Great Western ...	1907	4—6—0	14 10	5 6 | 4 10⅞ (coned)	9 0	8 2 7/16	3 2⅝	—	—	27.07	1988.65	—	—	154.26	2142.91	225	14½	26	6 8½	55 8	75 12	14 9	27 3	3 15	2 15
Great Western ...	1907-8	4—6—2	23 0	6 0 | 5 6 (extended wagon top)	9 0	7 2⅝	5 8⅝ (tapering to 4 11½ at top)	6 5 1/16	5 2 7/16	41.79	2673.45	—	545 in boiler barrel, 24.22 in firebox.	158.14	3400.81	225	15	26	6 8½	61 7	97 5	14 0	34 6	4 8	2 16
Lancs. and Yorks.	1908	4—6—0	15 0	5 7	8 11	—	—	—	—	27	2317	—	—	190	2507	180	16	26	6 3	59 1	77 1	13 5	25 2	4 8	3 1

[To face p. 46 of Vol. I.

TABLE VIII.—GREAT EASTERN FOUR-COUPLED CLASSES

Type.	Boiler. Barrel Length.	Boiler. Min. Outside Diam.	Boiler. Centre Line above Rail.	Pressure.	Type of Firebox.	Grate Area.	Total Heating Surface.	Cylinders. Diam.	Cylinders. Stroke.	Driving Wheel Diam.	Adhesion Weight.	Total Weight.	Engine Wheel-base.	Total Length with Tender.
	ft. in	ft. in.	ft. in.	lb. per sq. in.		sq. ft.	sq. ft.	in.	in.	ft. in.	tons cwt.	tons cwt.	ft. in.	ft. in.
4—4—0 (1900 class)	11 9	4 8	8 3	180	Ordinary	21.3	1630.5	19	26	7 0	33 4	50 6	20 3	53 0
4—4—0 (1850 class)	11 9	4 8	8 5	180	Belpaire	21.6	1706.58	19	26	7 0	34 9	51 14	20 3	53 0
4—4—0 (converted 2—4—0) ...	10 0	4 8	8 6	180	Belpaire	21.6	1476.2	18	24 / 25	7 0	32 17	47 16	18 3	50 $7\frac{1}{2}$
2—4—0 (760 class, "Belpaire")	10 0	4 8	8 6	180	Belpaire	21.6	1476.2	18	24 / 25	7 0	30 13	45 9	16 6	48 2
2—4—0 (760 class, "ordinary")	10 0	4 3	7 6	160	Ordinary	18	1217.08 / 1199.5	18	24 / 25	7 0	27 12	42 0	16 6	48 2
2—4—0 (mixed traffic) ...	10 0	4 3	7 6	140 / 160	Ordinary	18	1217.08 / 1199.5	17 / $17\frac{1}{2}$	26	5 8	26 3	40 6	16 6	48 2

TABLE IX.—REPRESENTATIVE GREAT WESTERN FOUR-COUPLED CLASSES

Class.	Boiler. Length of Barrel.	Boiler. Outside Diameter. Smoke-box End.	Boiler. Outside Diameter. Firebox End.	Firebox. Length Outside.	Firebox. Width Outside.	Firebox. Depth Inside.	Heating Surface. Tubes.	Heating Surface. Firebox.	Heating Surface. Total.	Grate Area.	Diameter and Stroke of Cylinders.	Driving Wheel Diam.	Adhesion Weight.	Total Weight.	Boiler Pressure.
	ft. in.	ft. in	ft. in.	ft. in.	ft. in.	ft. in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	in.	ft. in.	tons cwt.	tons cwt	lb. per sq. in.
"City"	11 0	4 $10\frac{3}{4}$	5 6	7 0	5 9 / 4 0	6 $6\frac{7}{16}$ / 5 $0\frac{7}{16}$	1692.14	128.21	1820.35	20.56	18×26	6 $8\frac{1}{2}$	36 2	55 6	195
"County" ...	11 0	4 $10\frac{3}{4}$	5 6	7 0	5 9 / 4 0	6 $6\frac{7}{16}$ / 5 $0\frac{7}{16}$	1692.14	128.21	1820.35	20.56	18×30	6 $8\frac{1}{2}$	34 6	55 6	200
						As compared with the converted "Badmintons"									
"Earl Cawdor"	11 6	5 5	5 5	6 4	4 0	7 1	1803.27	130.75	1934.02	17.85	18×26	6 $8\frac{1}{2}$	35 10	56 14	210

to extend the advantages of four-cylinder working as regards the balancing of reciprocating masses by arranging for two cylinders to drive on one axle and two on another, as in Mr. Drummond's earlier efforts. In the later London and South-Western engines of this type, which have the 4—6—0 wheel arrangement, and also in Mr. Churchward's " Star " class of 4—6—0 engines and their successors, with the 4—6—2 engine " Great Bear ", the cylinders are so arranged that the inside pair, placed well forward under the bogie platform, drive on the leading coupled axle, whilst the outside cylinders, placed farther to the rear, drive the middle pair of coupled wheels In the first engine of the kind, No. 40, an "Atlantic ", the outside cylinders drove, of course, on the rear pair of coupled wheels. Notwithstanding the increased cost of these locomotives, due to the employment of four cylinders with separate sets of valves, it seems certain that we shall see further examples of the practice in the future. Mr. Robinson, on the Great Central, has introduced yet another variety, viz. a *three*-cylinder balanced simple " Atlantic ", in which, as in the case of his compound engines, the two outside cylinders drive on the trailing and the inside cylinder on the leading coupled axle. The first example of a three-cylinder simple engine in this country was, of course, Mr. James Holden's celebrated " decapod " experimental tank engine, built for the Great Eastern in 1902.

Appended are the leading dimensions of the various four-cylinder simple engines to which reference has been made (Table X).

Many of the Great Western six-wheels coupled express engines are provided with four high-pressure cylinders, including the " Great Bear ", No 111, 4—6—2 type.

The " Great Bear ".—This interesting engine, an entirely new departure in British locomotive practice, may possibly become historic, representing as it does a revolution in design comparable with the pioneer Lancashire and Yorkshire " Atlantic " or the Great Eastern " decapod " tank engine. Its enormous boiler, with its centre line 9 ft. from the rails, sur-

TABLE XI

	Boiler.				Firebox.				Grate Area.	Heating Surface.		Working Pressure.
	Length of Barrel.	Greatest Outside Diameter.	Centre Line above Rail Level.	Length of Fire Tubes.	Length.	Width.	Height.			Firebox.	Total.	
							Front.	Back.				
	ft. in.	ft. in.	ft.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	sq. ft.	sq. ft.	sq. ft.	lb. per sq. in.
Great Western, 4—6—2	23 0	6 0	9	22 7	7 2⅜	5 8⅜	6 5⅞	5 2⅞	41.79	158.14	3400.81	225
Great Eastern, 0—10—0	15 6¼	5 4¼	9	16 1	6 0	7 0	5 4	5 4	42.0	131.7	3010	200

passes anything of the kind previously seen in this country, as will be shown by the following comparison between it and the previous " record " British locomotive boiler (Table XI).

Notwithstanding that the somewhat large wheel diameter of 6 ft. 8½ in. for six-coupled engines is retained, it has been found possible to reduce the rigid wheelbase of the six-coupled classes by 9 in., and by this means, combined with the provision of ample side play at the radial carrying wheels, the engine is easily able to negotiate any curves met with on the road. Eight-inch piston valves are employed and are worked by two sets of Walschaerts' gear arranged inside the frames. The bogie is of new design with spring side control, and the spring gear is equalized from the leading coupled wheel to the trailing carrying wheel.

Another novelty in design, so far as the Great Western is concerned, is the carrying of the tender on two four-wheeled bogies. With the exception that the wheelbase is shorter, these are identical with the engine bogie.

The following figures will serve to show how the " Great Bear " compares with an American " Pacific " engine approximating to it somewhat in design:

TABLE XII

	Baltimore and Ohio.	Great Western.
	4—6—2, No. 2100.	4—6—2, No. 111.
Track gauge, 4 ft. 8½ in. in both cases.		
Boiler:—		
Type	Straight.	Extended wagon top.
Outside diameter at front end	6 ft.	5 ft. 6 in.
Length of tubes	20 ,,	22 ,, 7 ,,
Working pressure per square inch	200 lb.	225 lb.
Firebox:—		
Length inside at base	9 ft.	7 ft. 2⅜ in.
Width inside at base	6 ft. 3¼ in.	5 ,, 8⅜ ,,
Grate area	56·5 sq. ft.	41·79 sq. ft.
Heating surface	3418·00 sq. ft.	3400·81 ,, ,,
Cylinders	two 22″ × 28″	four 15″ × 26″
Diameter of driving wheels	6 ft. 2 in.	6 ft. 8½ in.
Wheelbase:—		
Driving	13 ft. 2 in.	14 ft. 0 in.
Total	34 ,, 1½ ,,	34 ,, 6 ,,
Loaded weights:—		
On bogie	18 tons 2 cwt.	18 tons 12 cwt.
On coupled wheels	67 ,, 4 ,,	61 ,, 7 ,,
On trailing axle	17 ,, 4 ,,	17 ,, 6 ,,
Total	102 ,, 10 ,,	97 ,, 5 ,,
Per foot of driving wheelbase	5 ,, 2 ,,	4 ,, 8 ,,
Per foot of total wheelbase	3 ,, 0 ,,	2 ,, 16 ,,
Length over all—engine and tender	74 ft. 2 in.	71 ft. 2¼ in.
Tractive effort, taking m.e.p. at 90 per cent	33,000 lb.	29,430 lb.

London and South-Western Four-cylinder Simple Engines.—Several of the leading features of Mr. Drummond's efforts have already been noticed. In addition, attention may be called to an unusual practice in locomotive design in placing two duplex vertical feed pumps a little in front of the firebox. The feed water is heated by means of a pipe passing down from the inside cylinders under the axles to the rear end, connecting on the way with branches from the two outside cylinders and thus conveying part of the exhaust to the tender. This exhaust steam traverses a nest of sixty-five tubes of 1¼ in. external diameter and of 382 sq. ft. heating surface, placed in a well under the tender, and thus raises the temperature of the feed water.

The "Atlantic" Type.—Curious indeed has been the history of the "Atlantic" in this country. The type had already earned for itself a grand reputation, both in America and in France, when the first British examples made their appearance. The magnificent performances standing to the credit of the "Atlantics" were entirely independent of any question of steam expansion. The du Bousquet-de Glehn "Atlantics" are compounds, the New York Central "Atlantics" are simple engines.

When it had become evident that the increasing train loads were proving too much for the 4—4—0 engines on British trunk lines, the "Atlantic" was regarded almost in the light of the inevitable. Some builders have, however, preferred to utilize their larger boiler power in some other direction, and in some instances, with the praises of the "Atlantics" ringing in their ears, locomotive engineers have proceeded at once to place their large boilers above six-coupled wheels. This has led to the peculiar geographical distribution of the two types previously referred to. The fact is, of course, that so many different factors are at work on the problem of railway transit at any given moment that considerations which appear paramount on one line may be absolutely a negligible quantity on another. In the result, the Great Northern company, pioneers of the British "Atlantic" order, and possessing a large number of these engines, have no 4—6—0 express engines. Mr. Churchward, for the Great Western, has weighed the "Atlantic" in the balance and found it wanting. Mr. Urie has seen no reason to experiment with the 4—4—2 type, and it is almost certain that should the Midland find their present useful standard 4—4—0 engines overpowered, recourse would be had to six-coupled wheels. Mr. Robinson, on the Great Central, would appear to be by no means wedded to the "Atlantic" wheel arrangement, and distributes his favours impartially. All the companies forming the East Coast route—the Great Northern, the North-Eastern, and the North British—do much of their important duty with "Atlantics": the type is not seen on the West Coast route. This rejection in one direction of what is considered as deserving of confidence in another is one of the most striking examples in modern locomotive practice of the influence of a "local habitation and a name".

Limitations of "Atlantics".—The fact is that the "Atlantic", like many other excellent things, has its limitations. The Great Northern, with

R 4—4—2 TYPE

Railway.	Diameter of Driving Wheels.	Weight in Working Order.		Wheelbase.		Weight per Foot Run of		Remarks.
		On Driving Wheels.	Total.	Driving.	Total.	Driving Base.	Total Base.	
	ft. in.	tons cwt.	tons cwt.	ft. in.	ft. in.	tons.	tons.	
Great Northern	6 7½	31 0	58 0	6 10	26 4	4.54	2.20	Pioneer "Atlantics".
Lancashire and Yorks	7 3	35 0	58 15	7 6	27 9	4.66	2.12	Unique in having cylinders *inside*.
Great Northern	6 7½	32 0	60 0	—	26 9	—	2.21	One engine only.
Great Northern	6 7½	36 0	65 10	6 10	26 4	5.27	2.49	Standard class.
Great Northern	6 8	36 10	69 0	6 10	26 4	5.28	2.62	4-cylinder compound, capable of working as simple engine.
Great Northern	6 8	37 0	71 0	8 6	28 3	4.35	2.51	4-cylinder balanced compound supplied by Vulcan Foundry Company.
Great Northern	6 8	36 0	69 5	6 10	26 4	5.27	2.63	4-cylinder compound.
Great Central...	6 9	37 0	66 16	7 3	27 9½	5.10	2.40	——
Great Central...	6 9	37 0	67 12	7 3	27 9½	5.10	2.43	——
Great Central...	6 9	37 0	71 0	7 3	27 9½	5.10	2.55	3-cylinder balanced compound.
North-Eastern	6 10	39 0	72 18	7 7	28 0	5.14	2.60	——
North-Eastern	7 1¼	39 3	73 12	7 6	28 9	5.24	2.56	4-cylinder compound.
North-Eastern	6 10	40 0	76 15	7 7	29 1½	5.27	2.63	3-cylinder simple.
Great Western	6 8 6/16	33 7	64 13	7 0 8/8	27 10 8/8	4.73	2.32	De Glehn 4-cylinder compound "La France".
Great Western	6 8½	36 10	71 8	7 0 6/8	28 6½	5.18	2.50	Two 4-cylinder de Glehn compounds.
Great Western	6 8½	39 0	70 10	7 0	27 7	5.57	2.55	"Albion"—First G. W. "Atlantic".
Great Western	6 8½	39 12	74 10	7 0	27 9	5.66	2.61	"North Star"—4-cylinder simple.
London, Brighton, & North British...	6 7½	38 15	67 0	6 10	26 4	5.68	2.54	——
	6 9	40 0	74 8	7 3	27 9½	5.52	2.68	——
Erie (U.S.A.)	6 6	51 1	91 19	7 0	28 9	7.29	3.20	4-cylinder balanced compound.

[*To face p. 50 of Vol. I.*

TABLE XIII.—REPRESENTATIVE BRITISH LOCOMOTIVES OF "ATLANTIC" OR 4—4—2 TYPE

Railway.	Date.	Class.	Boiler Barrel. Length.	Boiler Barrel. Minimum Outside Diameter.	Boiler Barrel. Height of Centre Line above Rails.	Inner Firebox. Length at Base.	Inner Firebox. Width at Base.	Inner Firebox. Depth. Back.	Inner Firebox. Depth. Front.	Grate Area.	Heating Surface. Tubes.	Heating Surface. Firebox.	Heating Surface. Total.	Working Pressure.	Cylinders. No.	Cylinders. Diam.	Cylinders. Stroke.	Diameter of Driving Wheels.	Weight in Working Order. On Driving Wheels.	Weight in Working Order. Total.	Wheelbase. Driving.	Wheelbase. Total.	Weight per Foot Run of. Driving Base.	Weight per Foot Run of. Total Base.	Remarks.
			ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	lb. per sq. in.		in.	in.	ft. in.	tons cwt.	tons cwt.	ft. in.	ft. in.	tons.	tons	
Great Northern	1898	990	14 8⅜	4 6⅞	7 11	7 6¼	3 6¾	5 7⅛	6 3⅛	26.7	1302.1	140	1442.1	175	2	18½	24	6 7½	31 0	58 0	6 10	26 4	4.54	2.20	Pioneer "Atlantics".
Lancashire and Yorkshire	1899	1400	15 0	4 10	8 11⅜	7 5⅝	3 0	6 11½	6 11½	26.05	1877	175.8	2052.8	175	2	19	26	7 3	35 0	58 15	7 6	27 9	4.66	2.12	Unique in having cylinders *inside*.
Great Northern	1902	271	15 1¾	4 6⅞	—	—	—	—	—	24.5	1162.75	140.25	1303	175	4	15	20	6 7½	32 0	60 0	—	26 9	—	2.21	One engine only.
Great Northern	1903	251	16 3⅝	5 4½	8 8½	5 2½	5 11⅝	5 5⅜	5 8⅝	30.9	2359	141	2500	175	2	18½	24	6 7½	36 0	65 10	6 10	26 4	5.27	2.40	Standard class.
Great Northern	1905	292	16 3⅞	5 4⅝	8 8½	5 2⅛	5 11⅝	5 5⅜	5 8⅝	30.9	2359	141	2500	200	{ 2 / 2	13 / 16	20 / 26	6 8	36 10	69 0	6 10	26 4	5.28	2.62	4-cylinder compound, capable of working as simple engine.
Great Northern	1905	1300	11 11	5 1⅝	8 10	9 0	4 10½	4 9	6 4½	31.09	2344	170	2514	200	{ 2 / 2	14 / 23	26 / 26	6 8	37 0	71 0	8 6	28 3	4.35	2.51	4-cylinder balanced compound supplied by Vulcan Foundry Company.
Great Northern	1908	1421	14 6 (between tube plates)	5 4⅜	8 8½	5 11	5 11⅝	5 0½	5 7	30.9	2359	141	2500	175	{ 2 / 2	13 / 18	20 / 26	6 8	36 0	69 5	6 10	26 4	5.27	2.63	4-cylinder compound.
Great Central	1903	192	15 0	4 9½	8 6	7 9⅛	3 4⅛	4 7⅝	5 7⅝	26	1777.9	133.1	1911	200	2	{ 19 / 19½ }	26	6 9	37 0	66 16	7 3	27 9½	5.10	2.40	—
Great Central	1905	250	15 0	4 9½	8 6	7 9⅛	3 4⅛	5 5⅜	6 7⅝	26	1777.9	153.4	1931.3	200	2	{ 19 / 19½ }	26	6 9	37 0	67 12	7 3	27 9½	5.10	2.43	—
Great Central	1905	258	15 0	4 9½	8 6	7 9⅛	3 4⅛	5 5⅜	6 7⅝	26	1777.9	153.4	1931.3	200	{ 1 / 2	19 / 21	26 / 26	6 9	37 0	71 0	7 3	27 9½	5.10	2.55	3-cylinder balanced compound.
North-Eastern	1904	532	15 10½	5 6	8 11	8 3½	3 2½	6 4⅞	7 4⅜	27	2275.8	180	2455.8	200	2	20	28	6 10	39 0	72 18	7 7	28 0	5.14	2.60	—
North-Eastern	1906	730	15 0 (between tube plates)	5 0	8 10	8 4⅜	—	—	—	29	1916	180	2096	225	{ 2 / 2	14½ / 22	26 / 26	7 1½	39 3	73 12	7 6	28 9	5.24	2.56	4-cylinder compound.
North-Eastern	1911	Z & Z1	16 2⅜	5 6	8 11	8 3½	3 2½	6 4¾	7 4⅜	27	2160	{ 180 / 160 }	2340	180	3	{ 15½ / 16½ }	26	6 10	40 0	76 15	7 7	29 1½	5.27	2.63	3-cylinder simple.
Great Western	1904	102	13 7⅜	5 0	8 3¼	9 10	3 11⅞	5 2⅜	6 7½	29.5	2288.77	167	2455.77	227	{ 2 / 2	13⅜ / 22⅛	25⅜ / 25⅛	6 8⅛	33 7	64 13	7 0⅜	27 10⅜	4.73	2.32	De Glehn 4-cylinder compound "La France".
Great Western	1905	103-4	14 1⅜	4 11⅜	8 10⅝	10 9⅛	3 11⅜	5 0	7 0⅛	33.35	2582.7	173	2755.7	227	{ 2 / 2	14⅛ / 23⅜	25⅜ / 25⅛	6 8½	36 10	71 8	7 0⅜	28 6½	5.18	2.50	Two 4-cylinder de Glehn compounds.
Great Western	1905	171	14 10	(coned) { 4 10⅛ / 5 6 }	8 6	8 2⅛	{ 4 9 / 3 2⅜ }	5 0⅛	6 6⅛	27.07	1988.65	154.26	2142.91	225	2	18	30	6 8½	39 0	70 10	7 0	27 7	5.57	2.55	"Albion"—First G. W. "Atlantic".
Great Western	1906	40	14 10	(coned) { 4 10⅛ / 5 6 }	8 6	8 2⅛	{ 4 9 / 3 2⅜ }	5 0⅛	6 6⅛	27.07	1988.65	154.26	2142.91	225	4	14½	26	6 8½	39 12	74 10	7 0	27 9	5.66	2.61	"North Star"—4-cylinder simple.
London, Brighton, & S. Coast	1905	37	16 3⅞	5 4⅜	8 8½	5 2⅛	5 11⅝	—	—	31.09	2337.1	136.4	2473.5	200	2	18½	26	6 7½	38 15	67 0	6 10	26 4	5.68	2.54	—
North British	1906	868	15 0	5 4⅜	8 11	8 4¼	3 5¼	6 2¼	7 2	28.7	2071.4	184.8	2256.2	200	2	20	28	6 9	40 0	74 8	7 3	27 9½	5.52	2.68	—
											Compare above with														
Erie (U.S.A.)	1907	—	17 0 (length of tubes)	(wagon top) 5 11 (front end)	—	9 0	6 3	—	—	56.3	3434	188	3622	220	{ 2 / 2	15½ / 26	26 / 26	6 6	51 1	91 19	7 0	28 9	7.29	3.20	4-cylinder balanced compound.

[*To face p. 50 of Vol. I.*

a road of light gradients to work over, may well have found 4—4—2 engines all that could be desired to haul their main-line services, but Mr. Gresley has now introduced the 2—6—0 type for working some of the heavier expresses. Although the eastern section of the Lancashire and Yorkshire road is much heavier in character, the Manchester-Liverpool and other similar services on that line are often comparatively light in weight. For such work the "Atlantics" may serve well, but it is significant that Mr. Hughes has proceeded to the four-cylinder 4—6—0 type. A frequent and regular service with moderate loads at sustained high speed demands much steam, and ample heating and grate surface must be provided. So long, therefore, as the question remains one largely of firebox form and dimensions the "Atlantic" type offers special facilities by reason of the low pitch of the axle of the small pair of carrying wheels. Larger boilers could have been placed over the ordinary 4—4—0 wheel arrangement; but almost of necessity, in most cases, the enlarged firebox must have accompanied them, and as the box would have to be placed between the two driving axles the additional length would of course involve an extension of the coupled wheelbase and consequently an undesirable lengthening of the coupling rod.

But there is no doubt that when adhesion is the primary consideration the "Atlantic" must give place. Putting aside questions of economy for the moment, it must be acknowledged that under modern conditions the 4—6—0 may well in certain cases be as inevitable as the "Atlantics" in others. With extended non-stop runs, Mr. Churchward found the "Atlantics" deficient in haulage power for surmounting the exacting gradients in the West country. What his service requires is an engine capable of taking 300 tons or more at sustained high speed on a schedule involving an average speed of 1 mile per minute for long stretches including such a gradient as $2\frac{1}{4}$ miles of 1 in 42, maintaining a comparatively high rate of speed. And these conditions he found the "Atlantics" incapable of fulfilling. Nor can one imagine the type dealing successfully with the heavy West Coast Scotch trains on the Shap and Beattock inclines. It would seem, therefore, that, although the undoubted advantages of the type will secure it a field for useful work, the "Atlantic" cannot by any means fill the large place in British engineering practice that at one time seemed probable.

The leading particulars of the chief "Atlantic" classes running in this country are set forth in Table XIII, and similar information respecting the 4—6—0 classes in Table XIV.

CHAPTER III

Tank Engines

Nowhere else in the world are tank engines employed to anything like the extent to which their use has attained in the United Kingdom. The total number of locomotives working on our railways is well over 23,000, and of these not less than 40 per cent are tank engines, which even on some of the great trunk systems take up nearly 50 per cent of the total passenger-train mileage in addition to undertaking a prodigious amount of shunting and a proportion of the goods-train working. On some of the smaller lines, indeed, the traffic—goods and passenger alike—is worked exclusively by tank engines, whilst on some of the larger systems, such as the Great Eastern, the South-Eastern and Chatham, or the London and South-Western, where the short-distance passenger traffic assumes extensive proportions, they are employed in large numbers. On railways, again, such as the Great Western, London and North-Western, or the Lancashire and Yorkshire, passing through great industrial districts, their duties are almost infinite and their numbers correspondingly high.

Tank Engines for Express Work.—The great outstanding advantage offered by tank as compared with tender engines is that they are designed to run in either direction indiscriminately and with equal facility, and this consideration has had no small part in the tendency in recent years to increase their power and at the same time extend their sphere of operations. Some years ago the Great Western ran all the passenger trains —express and slow—on the Devon and Cornwall lines with tank engines of the 4—4—0 and 2—4—0 types with 5-ft. coupled wheels; these engines were afterwards converted to tender engines. In Mr. Drummond's early days on the London and South-Western he used 0—4—4 tanks with 5-ft.-6-in. coupled wheels on the London-to-Portsmouth and the Exeter-to-Plymouth services. This practice has also been discontinued. But for fast running with " semi-suburban " or " inter-urban " trains tank engines have long been generally employed on the London and South-Western, London Brighton and South Coast, South-Eastern and Chatham, Great Eastern, Great Northern, London and North-Western, Midland, and other lines. Recently, however, there has been an increasing disposition to employ tank engines on main-line duty, to run at a comparatively high rate of speed for distances of 50 to 100 miles and more with fairly heavy trains, water being picked up *en route*. The modern tank engine is therefore not infrequently provided with a large boiler, and as a consequence there is a marked increase in the adoption of the 4—4—2, 2—6—2, and 4—6—2 wheel arrangements. Significant of the change wrought in the functions of the tank engine is the fact that, generally speaking, these more powerful engines have been provided on lines other than those dealing

4—6—0 TYPE

Railway.	Diameter of Driving Wheels.	Weight in Working Order.		Wheelbase.		Weight per Foot Run of		Remarks.
		On Driving Wheels.	Total.	Driving.	Total.	Driving Base.	Total Base.	
	ft. in.	tons cwt.	tons cwt	ft. in.	ft. in.	tons.	tons.	
Highland ...	5 3½	42 0	56 0	13 3	25 0	3.17	2.24	——
Highland ...	5 9	43 17	58 17	14 3	26 3	3.08	2.22	——
North-Eastern	6 1½	49 10	66 0	14 0	26 0½	3.57	2.53	——
North-Eastern	6 8¼	51 19	67 2	15 2	27 6	3.39	2.44	——
Caledonian ...	5 0	42 17	57 8	11 3	23 9½	3.81	2.41	*Inside* cylinders.
Caledonian ...	6 6	53 9	70 1	15 0	28 8	3.56	2.44	*Inside* cylinders.
Caledonian ...	6 6	54 10	73 0	14 8	28 8	3.72	2.55	*Inside* cylinders.
Caledonian ...	5 9	49 0	64 0	13 4	25 10½	3.68	2.47	*Inside* cylinders.
Caledonian ...	5 0	46 8	60 8	11 3	28 9½	4.12	2.10	*Inside* cylinders.
Great Western	6 8½	54 16 54 4	72 0 70 4	14 9	27 1	3.72 3.68	2.66 2.59	——
Great Western	6 8½	55 8	75 12	14 9	27 1	3.76	2.78	4-cylinder simple.
London and North	5 3	44 0	60 0	11 6	24 6	3.83	2.86	4-cylinder compound.
London and North	6 3	48 10	65 15	13 7	26 8½	3.57	2.46	——
London and North	5 2½	44 4	63 0	13 7	26 8½	3.25	2.36	"Mixed traffic."
London and North	6 9	57	—	—	54 0	—	—	——
Great Central ...	6 0	50 1	65 8	14 0	26 1½	3.57	2.50	——
Great Central ...	6 9	52 12	67 15	14 6	26 9½	3.63	2.53	——
Great Central ...	5 3	51 19	67 8	14 0	26 1½	3.71	2.58	——
Great Central ...	6 6	54 10	70 10	14 6	26 9½	3.76	2.62	——
Glasgow and Sout	6 6	49 17	67 2	15 0	27 8	3.32	2.42	——
London and South	6 0	51 10	73 0	13 4	26 5	3.87	2.74	4-cylinder simple.
London and South	6 0	52 10	74 0	13 4	26 10	3.94	2.76	4-cylinder simple.
London and South	6 7	—	—	14 4	27 8	—	—	4-cylinder simple.
London and South	5 7	55 18	77 8	13 9	26 7½	4.2	2.76	——
Great Southern an	5 1¾	—	56 19	14 6	24 10½	—	2.29	——
Lancs. and Yorks.	6 3	59 1	77 1	13 5	25 2	4.4	3.06	4-cylinder simple.
Great Eastern	6 6	44 0	64 0	14 0	28 6	3.14	2.24	——
St. Louis and San (U.S.A.) ...	5 9	62 19	86 16	15 10	26 10	3.98	3.24	——

[*To face p. 52 of Vol. I.*

TABLE XIV.—REPRESENTATIVE BRITISH LOCOMOTIVES OF THE 4–6–0 TYPE

Railway.	Date.	Class.	Boiler Barrel. Length.	Boiler Barrel. Minimum Outside Diameter.	Boiler Barrel. Height of Centre Line above Rails.	Inner Firebox. Length at Base.	Inner Firebox. Width at Base.	Inner Firebox. Depth. Back.	Inner Firebox. Depth. Front.	Grate Area.	Heating Surface. Tubes.	Heating Surface. Firebox.	Heating Surface. Total.	Working Pressure.	Cylinders. No.	Cylinders. Diam.	Cylinders. Stroke.	Diameter of Driving Wheels.	Weight in Working Order. On Driving Wheels.	Weight in Working Order. Total.	Wheelbase. Driving.	Wheelbase. Total.	Weight per Foot Run of. Driving Base.	Weight per Foot Run of. Total Base.	Remarks.
			ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	lb. per sq. in.		in.	in.	ft. in.	tons cwt.	tons cwt.	ft. in.	ft. in.	tons	tons.	
Highland	1894	103	13 9	4 7⅝	7 4	7 0¼	3 2½	4 6⅛	5 8⅜	22.6	1559	113.5	1672.5	175	2	20	26	5 3½	42 0	56 0	13 3	25 0	3.17	2.24	—
Highland	1900	140	14 4½	4 8⅜	8 2	7 5⅛	3 6½	4 11½	6 3½	26.5	1916	134	2050	180	2	19½	26	5 9	43 17	58 17	14 3	26 3	3.08	2.22	—
North-Eastern	1899	2001	15 0	4 9	8 2	7 3½	3 2½	4 8	5 8	23	1638.86	130	1768.86	200	2	20	26	6 1½	49 10	66 0	14 0	26 0½	3.57	2.53	—
North-Eastern	1901	2111	15 10½	4 9	8 6⅛	7 3½	3 2½	4 8	5 8	23	1638.86	130	1768.86	200	2	20	26	6 8¼	51 19	67 2	15 2	27 6	3.39	2.44	—
Caledonian	1902	55	14 0	4 7	8 0	5 9	3 5	5 3½	6 0½	20.63	1800	105	1905	175	2	19	26	5 0	42 17	57 8	11 3	23 9½	3.81	2.41	*Inside* cylinders.
Caledonian	1903	49	17 4½	4 10⅜	8 6	—	—	—	—	26	2255	145	2400	200	2	21	26	6 6	53 9	70 1	15 0	28 8	3.56	2.44	*Inside* cylinders.
Caledonian	1906	903	17 7⅛	4 11⅞	8 6	7 9⅜	3 3½	5 0¼	6 3½	26	2211.75	148.25	2360	200	2	20	26	6 6	54 10	73 0	14 8	28 8	3.72	2.55	*Inside* cylinders.
Caledonian	1906	908	15 8⅜	4 11⅞	8 6	—	—	—	—	21	2050	128	2178	180	2	19	26	5 9	49 0	64 0	13 4	25 10½	3.68	2.47	*Inside* cylinders.
Caledonian	1906	918	14 0½	4 11⅞	8 6	—	—	—	—	21	1890	128	2018	175	2	19	26	5 0	46 8	60 8	11 3	28 9½	4.12	2.10	*Inside* cylinders.
Great Western	1902–3	98	14 10	(coned) 5 6 / 4 10⅛	8 6	8 2⅛	{3 2⅞ / 4 9}	5 0⅛	6 6⅞	27.07	1988.65	154.26	2142.91	{200 / 225}	2	18	30	6 8½	{54 16 / 54 4}	72 0 / 70 4	14 9	27 1	{3.72 / 3.68}	2.66 / 2.59	—
Great Western	1907	4001	14 10	(coned) 5 6 / 4 10⅛	9 0	8 2⅛	{3 2⅞ / 4 9}	5 0⅛	6 6⅞	27.07	1988.65	154.26	2142.91	225	4	14½	26	6 8½	55 8	75 12	14 9	27 1	3.76	2.78	4-cylinder simple.
London and North-Western	1903	1400	15 6	4 6⅞	8 3	—	—	—	—	20.5	1630	123	1753	200	{2 / 2}	15 / 20½	24 / 24	5 3	44 0	60 0	11 6	24 6	3.83	2.86	4-cylinder compound.
London and North-Western	1905	66	12 7⅜	4 11½	8 7	7 5⅛	3 4⅛	5 11	5 11	25	1908	133	2041	175	2	19	26	6 3	48 10	65 15	13 7	26 8½	3.57	2.46	—
London and North-Western	1907	285	12 6	5 0⅞	8 7	—	—	—	—	25	1840.5	144.3	1984.8	185	2	19	26	5 2½	44 4	63 0	13 7	26 8½	3.25	2.36	"Mixed traffic."
London and North-Western	1913	2222	14 6	5 2	—	9 6	4 1	—	—	30.5	1160.9	171.2 (superheater) / 486.3	1814.4	175	4	16	24	6 9	57	—	—	54 0	—	—	—
Great Central	1902	1067	15 0	4 9	8 3	7 9	4 0½	—	—	23	1622	126	1748	180	2	19	26	6 0	50 1	65 8	14 0	26 1½	3.57	2.50	—
Great Central	1904	195	15 0	4 9½	8 6	7 9⅛⅜	3 4⅛	4 7⅞	5 7⅞	26	1777.9	133.1	1911	180	2	{19½ / 19}	26 / 26	6 9	52 12	67 15	14 6	26 9½	3.63	2.53	—
Great Central ..	1906	1105	15 0	4 9½	8 3	7 0⅛⅜	3 4	5 1⅜	6 0⅜	23.4	1777.9	131.6	1909.5	200	2	19½	26	5 3	51 19	67 8	14 0	26 1½	3.71	2.58	—
Great Central	1906	1097	15 0	4 9½	8 6	7 9⅛⅜	3 4⅛	4 7⅞	5 7⅛	26	1777.9	133.1	1911	200	2	19½	26	6 6	54 10	70 10	14 6	26 9½	3.76	2.62	—
Glasgow and South-Western	1903	381	15 5	4 8	8 3	7 4⅛⅜	3 3½	5 11⅛	—	25	1721	131	1852	180	2	20	26	6 6	49 17	67 2	15 0	27 8	3.32	2.42	—
London and South-Western ..	1905	330	13 9	5 6	9 0	8 11½	4 0½	5 10¼	6 1¼	31.5	2210	160 / 357 (water tubes)	2727	175	4	16	24	6 0	51 10	73 0	13 4	26 5	3.87	2.74	4-cylinder simple.
London and South-Western..	1907	335	13 9	5 6	9 0	8 11½	4 0½	5 10¼	6 1¼	31.5	2210	160 / 357 (water tubes)	2727	175	4	16½	26	6 0	52 10	74 0	13 4	26 10	3.94	2.76	4-cylinder simple.
London and South-Western...	1912	462	13 9	4 9½	9 3½	—	—	—	—	31.5	1636	140 / 200 (water tubes)	1976	200	4	15	26	6 7	—	—	14 4	27 8	—	—	4-cylinder simple.
London and South-Western..	1920	498	13 9	5 0	8 7½	9 0	—	3 9	5 9	30	1252	162	1414	180	2	21	28	5 7	55 18	77 8	13 9	26 7½	4.2	2.76	—
Great Southern and Western	1906	365	14 9⅜	4 10½	8 9	6 4½	3 10½	5 6⅜	6 5½	24.8	1466.75	133	1599.75	160	2	19½	26	5 1⅜	—	56 19	14 6	24 10½	—	2.29	—
Lancs. and Yorks.	1908	1506	15 0	5 7	8 11	—	—	—	—	27	2317	190	2507	180	4	16	26	6 3	59 1	77 1	13 5	25 2	4.4	3.06	4-cylinder simple.
Great Eastern	1912	1500	12 6	5 0	8 6	8 6	4 0½	4 11⅛⅝	5 11⅞⅝	26.5	1775.5	143.5	1919	180	2	20	28	6 6	44 0	64 0	14 0	28 6	3.14	2.24	—
											Compare above with														
St. Louis and San Francisco (U.S.A.)	1908	—	15 1½ (length of tubes)	(wagon top) 5 8 (front end)	9 8	8 5⅞	5 7¼	4 11⅛	6 5⅜	47.7	2867	172	3039	200	2	23	26	5 9	62 19	86 16	15 10	26 10	3.98	3.24	—

[To face p. 52 of Vol. I.

with the bulk of the metropolitan suburban passenger traffic, the working of which has hitherto been regarded as the most valuable duty performed by tank engines. It is true that the Great Eastern, Great Northern, London and South-Western, London Brighton and South Coast, and South-Eastern and Chatham—the companies, apart from the Midland and the London and North-Western, largely concerned with the metropolitan suburban passenger traffic—have been providing increased power; but, except in the case of the Brighton Company, they have not advanced in the design of powerful tank engines to the level attained by some of the other lines, as, for instance, the Great Western, the North-Eastern, the Great Central, the Lancashire and Yorkshire, and the London and North-Western, being content to rely upon the deservedly good repute of the older types.

0—4—4 Type.—Undoubtedly one of the most popular of the older types of tank engines was the 0—4—4 or four-coupled trailing bogie—a type which from time to time has been the subject of strictures on the part of Board of Trade inspecting officers on the alleged ground of liability to derail unless run bunker first. There are advantages in the design which cannot be ignored, such as the opportunity it affords to narrow down the rigid wheelbase and to provide a firebox of ample proportions, and the engines are simple in detail and cheap to construct. Moreover, it must be said that facts scarcely support the view above referred to, and the daily work of large numbers of engines of the type would seem to be a sufficient reputation. They have been largely built by the South-Eastern and Chatham, London and South-Western, Great Eastern, Great Northern, Midland, North-Eastern, Lancashire and Yorkshire, Caledonian, Great Southern and Western, and London Brighton and South Coast, but have not been used by the Great Western, the London and North-Western, or the Great Central. With this type the cylinders are within the frames and drive on the rear coupled wheels.

0—6—0 Type.—The 0—6—0 type is found in very large numbers, but these engines are in the main confined to shunting and marshalling duty and the working of short-distance goods trains. They are, however, largely employed on the Great Eastern in the working of suburban passenger trains with frequent stops at short intervals. One service on this line dealt with by these engines involved the haulage of trains of seventeen carriages, weighing, when fully occupied, 235 tons and measuring 483 ft. from end to end, over $10\frac{3}{4}$ miles of most difficult road, with no fewer than fourteen intermediate stops, in forty minutes. To accomplish this the engine must average a running speed of from 20 to 22 miles per hour, and accelerate at the rate of 1 ft. per second per second. Needless to say, engines of this type give the utmost satisfaction.

These Great Eastern 0—6—0 tanks, like the vast majority of those to be found on the North-Eastern, Midland, London Brighton and South Coast, Caledonian, North British, and Great North of Scotland, have wing water tanks; but on the London and North-Western, the Lancashire and

Yorkshire, the Great Northern, the Caledonian, the Rhymney, and especially on the Great Western, they are of the saddle-tank class.

0—6—2 Type.—Many companies using six-coupled tank engines secure a comparatively powerful locomotive with increased bunker accommodation by adding a pair of " radial " wheels beneath the footplate. This popular and serviceable type may be roughly divided into two classes—one with coupled wheels 5 ft. and upwards in diameter used chiefly for passenger work, and the other with coupled wheels of less diameter employed mainly on goods traffic. The type is not yet seen on some lines, but its use is widespread, the London and North-Western, Lancashire and Yorkshire, North Eastern, London Brighton and South Coast, Great Central, North British, Cardiff, Rhymney, Taff Vale, and Barry companies employing such engines somewhat extensively. One of the finest examples is the Great Northern class of passenger tanks for metropolitan traffic, a powerful machine with a boiler giving 1250 sq. ft. of heating surface and 20·8 sq. ft. of grate, 18-in.-by-26-in. cylinders, and 5-ft.-7½-in. coupled wheels (see p. 76).

0—6—4 Type.—A variant of the 0—6—2 type is found on a few lines, consisting of the substitution of a four-wheeled bogie for the pair of " radial " wheels. A fine example of this practice is afforded by a type of Midland tanks (p. 75). It is distinguished by several interesting features in design. Side play to the extent of 1¼ in. is allowed the leading axle, and 5½ in. in the case of the trailing bogie. By this means the engine, although its wheel base is 29 ft., can take with the greatest ease curves of 4 chains radius. With large side tanks extending to the front line of the smokebox, and a hind tank, the engine can carry 2250 gall. of water, which is taken from the track troughs when running in either direction by a well-designed either-way water pick-up arrangement. Ready access to the motion is obtained by cutting away the side tanks to the necessary extent between the leading and driving wheel centres. Further examples of this type are found on the Wirral Railway, the Great Northern (Ireland), and the Sligo Leitrim and Northern Counties, with a powerful " banking " class on the Highland.

4—4—4 Type.—The bulk of the traffic on the Wirral line, however, is dealt with by a class of twelve-wheeled tank engines. These engines are four-coupled with four-wheeled bogies at either end. A few tanks of similar type are met with on the North Eastern and Midland and South-Western Junction lines. The latest example of the 4—4—4 type is that for the Metropolitan Railway for working passenger trains on the Aylesbury line. These engines have outside cylinders and piston valves with Walschaerts' valve gear.

Earlier 2—6—2 Type.—A powerful six-coupled tank engine is that of the 2—6—2 type. Engines of the class were introduced on the Great Western and the Lancashire and Yorkshire in 1903, and are at present almost confined to those lines. These engines represent the first sustained effort to provide tank engines of largely increased power, in each case resulting from tentative endeavours in the same direction (p. 76).

The 2—4—2 Forerunners on the Great Western and Lancashire and Yorkshire.—During the regime of Sir John Aspinall at Horwich, the Lancashire and Yorkshire company built for working some of their heavier trains a class of 2—4—2 tank engines with " radial " pairs of leading and trailing wheels and inside cylinders, and provided with water pick-up apparatus operative when running in either direction, thus being veritable " double-enders ". In 1901 the Great Western followed with a more powerful locomotive of the same type, with the same provision as regards radial axleboxes, inside cylinders, and either-way water pick-up apparatus. Towards the close of 1903, Mr. Hoy on the Lancashire and Yorkshire, and Mr. Churchward on the Great Western, turned out the first of a series of 2—6—2 tank engines, each in its way a decided advance on the 2—4—2 type from which it sprang.

Later 2—6—2 Type.—Mr. Hoy gave his engine the standard Lancashire and Yorkshire eight-coupled goods boiler with Belpaire firebox, which is practically also the standard express passenger (4—4—2) boiler and inside cylinders 19 in. by 26 in. Whilst providing a third pair of coupled wheels he retained the radial axleboxes for the leading and trailing axles, and he adhered to coupled wheels of 5 ft. 8 in. diameter. Mr. Churchward employed one of his coned boilers. He used 18-in-by-30-in. cylinders, placing them outside the frames to drive on the middle pair of drivers, and substituted a leading two-wheeled pony truck for the leading axle with radial boxes, and increased the diameter of the driving wheels from 5 ft. 2 in. to 5 ft. 8 in. In 1905 he built another series of these engines of smaller power, with 16½-in.-by-24-in. cylinders and driving wheels only 4 ft. 1½ in. diameter, which are used for branch and suburban working, whilst towards the close of the same year he reverted to the larger boiler and cylinders in a tank engine of the 4—4—2 type with coupled wheels of his standard diameter of 6 ft. 8½ in. for express work, the engine being practically a " County " 4—4—0 express locomotive with side tanks, bunker, and an additional pair of carrying wheels. The cylinders, of course, drive on the leading pair of coupled wheels.

4—4—2 Tanks.—Here, again, Mr. Churchward, although in this case not by any means first in the field as regards the wheel arrangement, showed the way with respect to power considerations. Tank engines of the 4—4—2 type of no great boiler capacity had long been in use on many lines. On the London Tilbury and Southend, for instance, the whole passenger duty was taken by such engines with outside cylinders, driving, as in the case of the Great Western engines of the same type and the North London engines, on the leading pair of coupled wheels. Mr. Churchward was followed by Mr. Whale on the London and North-Western with a still more powerful engine, whilst later examples are to be found on the Brighton, the North Stafford, and the Dublin and South-Eastern (see p. 77).

2—4—2 Type.—Tank engines of the 2—4—2 type are found largely on the London and North-Western and the Lancashire and Yorkshire. In the case of the former some have radial boxes to both leading and trailing

axles and some to the trailing axle only; the Lancashire and Yorkshire engines have the radial boxes at both ends. The type is also met with to a large extent on the Great Eastern, North-Eastern, and other lines in addition to the Great Western.

4—6—0 Type.—Another interesting type, at present employed to a slight extent only in tank engines, is that possessing six-coupled wheels with a leading four-wheeled bogie. This type was some years ago introduced on the Cork Bandon and South Coast Railway, Ireland, and Mr. Worsdell in 1908 built ten such engines for working heavy excursion traffic over the coast-line between Scarborough and Whitby, where the gradients are very severe. There is on this run in the one direction a continuous adverse gradient for 4½ miles, of which 2¼ miles is at 1 in 40, and another for 2¼ miles, two-thirds of which is also at 1 in 40. In the opposite direction rising gradients of 3 miles and 3¾ miles in length are met with, including ¾ mile and 3 miles respectively of 1 in 40 (p. 78).

0—8—0 and 0—8—2 Types.—Among the types less frequently used may be mentioned the 0—8—0 Caledonian engines with 62 tons 16 cwt. available for adhesion and the few 0—8—2 which on the Great Northern shared with Mr. Holden's Great Eastern "decapod" the ill luck of proving too heavy for the road over which they were intended to work. The Barry and the Port Talbot companies each possess a few powerful 0—8—2 tank engines, the trailing axle running in radial boxes, which show very good results in dealing with heavy mineral trains on difficult roads. On one section of the Barry with short gradients of 1 in 100 and 1 in 80 a load of 1300 tons is brought down from the collieries, and "empties" of a total tare of 480 tons taken up. On another section, where 4¼ miles of 1 in 120 and 2 miles of 1 in 127 have to be negotiated, the loads are 600 tons down and 270 up.

The most interesting examples of the 0—8—2 type, however, are undoubtedly Mr. Hughes's class, designed for "banking" and heavy coal shunting on steep inclines at Accrington and the Aintree and Fazakerly sidings at Liverpool. With 2198 sq. ft. of heating surface and an ample grate no difficulty is experienced in supplying 21½-in.-by-26-in. cylinders with steam at 180 lb. pressure, and all but 16 of the total weight of 84 tons is available for adhesion. The 17 ft. 11½ in. of rigid wheelbase is, moreover, considerably eased by the second and third pairs of wheels being flangeless with broadened tires.

Great Western "Consolidation" Tanks.—Mr. Churchward has provided for heavy coal traffic in South Wales the first examples of the reverse wheel arrangement (2—8—0) for tank engines. Here we have 70 tons in weight concentrated on a driving wheelbase of 20 ft., easement in this case being given by the provision of sliding axleboxes to the trailing wheels and spherical joints to the coupling rods. Mr. Churchward built nothing without superheating apparatus, and this provision has therefore been made in the boiler, which is of his usual standard coned type.

0—8—4 and 4—8—0 Banking Tanks.—In 1908 Mr. Robinson of

the Great Central built several very heavy eight-coupled tank engines with trailing bogie, to work the mineral trains up to the " hump " in the Wath Concentration Yard (p. 78). To push over 1000 tons up a gradient of 1 in 109 is no mean achievement, and demands that the engine shall have great adhesion power and a constant and equal turning effort at the cranks; hence the provision of three high-pressure cylinders and cranks set at 120 degrees to each other. In 1909 Mr. Worsdell followed with a somewhat smaller class for heavy shunting work in the North-Eastern Company's yards. These engines were also three-cylinder simples, arranged as in Mr. Robinson's class, but with the bogie brought to the leading end.

4—6—2 Type.—Nothing has been so typical of the extended use of tank engines during the past few years as the growing disposition to employ the " Pacific " wheel arrangement in this connection. These engines are already to be found on the Great Central (p. 78), London Brighton and South Coast, London and South-Western, London and North-Western, and the North-Eastern lines. Sir Vincent Raven's class on the North-Eastern is employed mainly on heavy mineral traffic; the others are devoted to long-distance fast passenger trains. Following Mr. Worsdell's practice in the 4—8—0 " humping " engines, of which they are in some respects reminiscent, the North-Eastern 4—6—2 tanks are of the three-cylinder simple type, whilst the other companies' engines have two high-pressure cylinders. Again, the Great Central and the Brighton examples are superheated engines, the North-Eastern are not, whilst some of the London and North-Western engines have this provision and others are without it. The Brighton company possesses two of these engines, one (" Abergavenny ") built by Mr. Marsh, and the other (" Bessborough ") by his successor, Mr. R. J. Billinton. Both haul heavy express trains from one end of the line to the other, and the train known as " The Southern Belle ", which is scheduled to perform the run of 50½ miles between Victoria and Brighton in 60 minutes, is often drawn by " Abergavenny ", " Bessborough ", or one of the " Baltics ". The engines have much in common from the point of view of design; but in one important particular " Bessborough " differs from " Abergavenny " —it has Walschaerts' valve gear (p. 75).

4—6—4 Type.—The only examples of the " Baltic " type of tank engine in this country are those on the London Brighton and South Coast Railway, designed by Mr. Billinton, and eight on the Midland Railway, designed by Mr. Robert H. Whitelegg, now Chief Mechanical Engineer of the Glasgow and South Western Railway. In this large and powerful tank engine, possibly the " last word " for some time to come in such design, we have ample opportunity for comparison, for careful observation and logical deduction. It may well be that in the " Baltic " tank we have arrived at a type which, furnished, as it may be and is, with standard main-line boiler, and other equipment, will go far to solve the problem of fast inter-urban traffic over distances of as much as 100 miles.

For chief dimensions of representative tank engines see Table XV.

TABLE XV.—TYPICAL TANK ENGINES

Type.	Railway.	Date.	Total Heating Surface.	Grate Area.	Working Pressure.	Cylinders.			Diameter of Coupled Wheels.	Weight in Working Order.		Wheelbase.	
						Position.	Diameter.	Stroke.		Adhesion.	Total.	Driving.	Total.
			sq. ft.	sq. ft.	lb per sq. in.		in.	in.	ft. in.	tons cwt.	tons cwt.	ft. in.	ft. in.
0—4—4	L. and S.-W. ...	1906	1191.68	20.36	175	Inside	18½	26	5 7	—	54 13	—	23 7
0—6—0	Midland	1900	1252	16.0	150	Inside	18	26	4 6½	48 16	48 16	16 6	16 6
	Great Eastern ...	1904	988.17	14.5	180	Inside	16½	22	4 0	42 7	42 7	13 10	13 10
0—6—2	Great Northern ...	1907	1249.8	20.8	170	Inside	18	26	5 8	—	—	16 3	23 9
	Rhymney	1905	1419.5	21.5	175	Inside	18½	26	4 6	54 1	66 19	15 3	21 9
	North British ...	1909	1309	16.6	175	Inside	18	26	4 6	—	62 19	15 6	22 6
0—6—4	Midland	1907	1331	21.1	175	Inside	18½	26	5 7	52 13	72 8	16 6	29 0
	Highland	1909	1268	22.43	180	Inside	18½	26	5 0	49 0	69 0	15 6	27 3
2—6—2	Lanc. and York. ...	1903	2038.64	26.05	180	Inside	19	26	5 8	52 8	77 10	12 4	27 7
	Great Western ...	1903	1517.89	20.35	195	Outside	18	30	5 8	50 13	72 3	14 9	31 9
	Great Western ...	1905	1272.0	16.83	165	Outside	16½	24	4 1½	40 0	55 15	11 6	26 6
	Dublin and S.-E. ...	1911	1194.2	20	175	Inside	18	20	6 0	—	63 0	—	—
	L. B. and S. C. ...	1907	1623	24.0	180	Inside	19	26	6 9	38 0	73 0	8 9	30 11
4—4—2	L. and N.-W. ...	1906	1939	22.4	175	Inside	19	26	6 3	39 10	75 15	10 0	32 7½
	Great Western ...	1906	1517.89	20.35	195	Outside	18	30	6 8½	37 0	75 0	8 6	32 0
	North Staffordshire	1911	1281	21	160	Inside	20	26	6 0	—	—	9 6	31 1½
	Lanc. and York. ...	1893	1216.41	18.75	160	Inside	18	26	5 8	34 15	59 3	8 7	24 4
2—4—2	Great Eastern ...	1893	1199.5	18.0	160	Inside	17½	24	5 8	29 6	58 12	8 9	23 3
	Great Western ...	1901	1561.65	21.35	180	Inside	17	24	5 2	—	64 12	—	—
4—6—0	North Eastern ...	1908	1312	23.0	170	Inside	19	26	5 1¼	52 0	69 0	12 6	26 3
0—8—0	Caledonian... ...	1903	1189	19.5	175	Inside	19	26	4 6	62 16	62 16	19 0	19 0
0—8—2	Barry	1903	1476	22.75	150	Outside	20	26	4 3	62 16	74 16	15 5	22 11
	Great Northern ...	1904	1043.7	17.8	175	Inside	20	20	4 7½	58 5	70 5	17 8	25 2
	Lanc. and York. ...	1909	2198	25.6	180	Inside	21½	20	4 6	68 0	84 0	17 11½	24 6
0—8—4	Great Central ...	1908	1931	26.0	200	2 outside, 1 inside	18	26	4 8	73 12	96 11	17 1	30 8
2—8—0	Great Western ...	1910	1566.74	20.56	200	Outside	18½	30	4 7½	70 0	78 0	20 0	28 9
4—8—0	North-Eastern ...	1909	1310	23	175	2 outside, 1 inside	18	26	4 7¼	66 17	84 15	15 3	29 0
4—6—2	L. and N.-W. ...	1910	1475	23.9	175	Inside	18½ / 20	26	5 8½	44 10	78 0	14 0	33 9
	North-Eastern ...	1910	1648	23	180	2 outside, 1 inside	16½	26	4 7½	55 12	87 8	14 6	—
	L. B. & S. C. ...	1910	1865	25	160	Outside	21	26	6 7½	56 0	86 0	—	—
	Caledonian ...	1917	1716	21.5	170	Outside	19½	26	5 9	55 1	91 13	13 3	33 1
4—6—4	L. B. & S. C. ...	1914	2070	26.7	170	Outside	22	26	6 9	56 10	98 0	14 9	40 0
	Midland	1913	1446	25	160	Outside	20	26	6 3	—	—	13 10	38 10½

CHAPTER IV

Goods Engines

Modern development in the design of British locomotives for goods traffic has closely followed on the lines of the advance in express passenger practice; that is to say, there has been the same marked tendency towards enhanced boiler power combined with smaller coupled wheels. Indeed, in many instances a decrease in the driving-wheel diameter, more pronounced than in the case of the express locomotive, in order to secure the maximum haulage power rather than speed, sometimes accompanied by some slight change in cylinder capacity and firebox dimensions, forms the only material point of difference between the passenger and the goods engines of modern design.

Development of Goods Engines.—Prior to the introduction of the large boiler the six-coupled (0—6—0) type was the only design favoured for goods work. It was " standard " practice, speaking generally, throughout the land, and for the present purpose may be regarded in much the same light as the 4—4—0 passenger engines. Subsequent developments have resolved themselves into provision for dealing more rapidly with perishable traffic, such as milk, meat, fish, fruit, flowers, and vegetables, where early arrival at market is essential, and also in relieving the congested state of the line by running much heavier trains of the more weighty traffic in coal, iron, stone, &c. The requirements in both cases involved the use of larger boilers. As regards the wheel arrangements, the demand for higher speed has naturally involved the employment of leading wheels or a bogie, whilst increased tractive power has been attained by coupling up another pair of wheels. Thus we find 2—6—0 and 4—6—0 engines performing for goods traffic the functions of the passenger " Atlantics ", and 0—8—0 and 2—8—0 locomotives those of the passenger " ten-wheelers " or 4—6—0 classes.

0—6—0 Type.—However, a very fair share of the goods traffic of the country is still taken by the old 0—6—0 classes. Such a line as the Great Eastern, for example, relies entirely on this type for its merchandise traffic —whether ordinary goods or mineral, while even the Midland, with all its enormous mineral traffic, is satisfied with the performances of the six-wheeled all-coupled type. Table XVI gives the leading dimensions of the 0—6—0 engines on the chief British lines employing them.

2—6—0 " Mogul " Type.—British practice in goods locomotives is, in respect of wheel arrangement, in curious contrast to that abroad. The 0—6—0 engines which do such good work here have few fellows to-day in other countries.

The 2—6—0 is apparently a coming standard type for mixed traffic work on British railways. The importance, under present high costs

TABLE XVI.—TYPICAL o—6—o GOODS ENGINES

Railway.	Boiler Barrel. Length.	Boiler Barrel. Minimum Diameter Outside.	Working Pressure.	Grate Area.	Heating Surface. Tubes.	Heating Surface. Firebox.	Heating Surface. Total.	Cylinders. Diameter.	Cylinders. Stroke.	Diameter of Driving Wheels.	Weight in Working Order.
	ft. in.	ft. in.	lb. per sq. in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	in.	in.	ft. in.	tons cwt.
Great Eastern	11 9	4 8	180	21.6	1588.88	117.7	1706.58	19	26	4 11	45 8
Great Northern	10 1	4 $3\frac{7}{8}$	170	17.8	1020.7	103.1	1123.8	$17\frac{1}{2}$	26	5 $1\frac{1}{2}$	38 8
North-Eastern	—	5 0	200	20	1531	127	1658	$18\frac{1}{2}$	26	4 $7\frac{1}{4}$	—
Great Central	11 0	5 0	180	19.5	1322	130	1452	$18\frac{1}{2}$	26	5 1	54 14
Midland	10 6	4 8	175	21.1	1302.9	125	1427.9	$18\frac{1}{2}$	26	5 3	43 16
London Brighton and South Coast ...	10 $10\frac{3}{4}$	5 0	170	18.64	1183.41	101.27	1284.68	$17\frac{1}{2}$	26	5 0	—
South-Eastern and Chatham	10 9	4 7	160	17	1089.32	110.68	1200	$18\frac{1}{2}$	26	5 2	43 16
Cambrian	10 3	4 $4\frac{1}{3}$	160	20.5	1131	110.7	1241.7	18	26	5 $1\frac{1}{2}$	41 13
North British	10 6	5 3	180	19.25	1661	133	1794	$18\frac{1}{2}$	26	5 0	48 14
Caledonian	—	4 $8\frac{1}{8}$	160	20.63	—	—	1403	$18\frac{1}{2}$	26	5 0	45 14
Highland	10 6	4 4	175	20.37	1061.1	246	1307.1	$18\frac{1}{4}$	26	5 $0\frac{1}{2}$	—
Great Southern and Western	11 3	4 $9\frac{1}{4}$	160	24.8	1403	132	1535	19	26	5 $1\frac{3}{4}$	49 3
Midland Great Western...	—	4 10	175	20	1213	140	1353	$18\frac{1}{2}$	26	5 3	47 10

TABLE XVII.—"MOGUL" GOODS ENGINES

Railway.	Boiler Barrel. Length.	Boiler Barrel. Minimum Diameter Outside.	Working Pressure.	Grate Area.	Heating Surface. Tubes.	Heating Surface. Firebox.	Heating Surface. Total.	Cylinders. Diam.	Cylinders. Stroke.	Diameter of Driving Wheels.	Weight in Working Order. On Drivers.	Weight in Working Order. Total.
	ft. in.	ft. in.	lb. per sq. in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	in.	in.	ft. in.	tons cwt.	tons cwt.
Midland (Baldwin built) ...	10 $5\frac{3}{4}$ (between tube plates)	4 8	180	16.6	1247.1	125.3	1372.4	18	24	5 0	37 2	44 15
Great Western (1904) ...	11 $4\frac{3}{4}$ (between tube plates)	4 $10\frac{7}{8}$ / 5 6	195 / 200	20.56	1689.82	128.3	1818.12	18	26	4 $7\frac{1}{2}$	49 13	56 15
Great Western (1911) ...	11 0	4 $10\frac{3}{4}$ / 5 6	200	20.56	1228.02 / 215.8	122.92	1566.74	$18\frac{1}{2}$	30	5 8	52 12	62 0
Great Southern & Western	11 3	5 0	160	24.8	1446.5	138.5	1585	19	26	5 $1\frac{3}{4}$	—	53 7

of operating, of "balancing" engine working makes the most economical class of engine that one which will work an express passenger train in one direction and can bring back a goods train an hour or so later. This the 2—6—0 is admirably suited to do. With, say, 5-ft.-8-in. wheels, the "diameter speed" is 68 miles per hour, which a 2—6—0 engine with these wheels can well attain.

During the "reign" of Mr. Massey Bromley the 2—6—0, or "Mogul", type made its debut on the Great Eastern, but these engines have long since disappeared. In 1896 two similar engines were supplied, by Messrs. Beyer, Peacock, & Co., to the Midland and South-Western Junction Railway. Between 1899 and 1901 the public agitation in favour of the "Americanizing" of our railways led to a small "boom" in "Moguls". During this period engines of this type were supplied by two American locomotive-building firms to the Great Northern, Midland, and Great Central companies. These engines were delivered with every sign of their American origin, although some attempt was made to meet British outlines. The result was not altogether pleasing from the point of view of appearance, and it might have been well to give the builders absolutely *carte blanche*. However, the locomotives were badly wanted, and they were handed over with characteristic American celerity and with that entire absence of all attempt at "finish" so noticeable in American practice. The engines undoubtedly did good work, but they were wasteful in both fuel and oil, and once again they demonstrated the inevitable failure of the exotic in British locomotive practice.

The Great Northern have recently developed an extremely efficient class of three-cylinder 2—6—0 engines, which work fast passenger trains besides hauling coal trains.

The London Brighton and South Coast are also developing the 2—6—0 type for passenger and freight traffic.

Great Western "Moguls".—The first Great Western "Moguls" were built in 1896–1900, during Mr. Dean's term, when that gentleman was seeking means to increase the haulage power of the company's six-coupled goods engines. In 1896, and again in 1899, he tried a leading bogie to accommodate a larger boiler with wide firebox, adding in the latter case a combustion chamber. Both engines, however, proved unsatisfactory in actual working, and were very short-lived. A better fate attended the six-coupled goods engines of his design which were during the period referred to turned out of shops with a two-wheeled Bissel bogie truck in front. These engines, in common with others of the same type, have outside frames and, of course, outside cranks for the coupling rods. The more recent additions have the standard coned boiler, whilst all exhibit the now familiar Great Western features of the saddle for supporting the extended smokebox, the large Belpaire firebox, the absence of the dome, &c. During recent years the company has added to its stock of "Consolidation" (2—8—0) goods engines, but the 2—6—0 class are doing extraordinarily good work on express, slow passenger, and fast goods.

Great Southern and Western "Moguls".—The Irish "Moguls"

referred to above are the outcome of the efforts made by the Great Southern and Western to deal more satisfactorily with the increased traffic resulting from the opening of the Fishguard-Rosslare route between Britain and Ireland. A class of 0—6—0 goods engines, of which the more recent were supplied in 1904, have been rebuilt with longer frames carried on six-coupled wheels and a leading pair with radial axleboxes. The leading dimensions of more recent Great Western engines of the type are shown contrasted with the Midland American " Moguls " (Table XVII).

4—6—0 Type.—Mr. Dean was anticipated in the employment of the 4—6—0 type for goods traffic by Mr. D. Jones, the pioneer in this design, on the Highland, the engines with this wheel arrangement having been specially provided by the latter for hauling goods traffic over the difficult gradients on his system. Since then the merits of the type have been fully recognized for dealing with any class of traffic where speed and haulage considerations must receive equal attention, and many of the lines possessing such locomotives utilize them much on the lines of the old " mixed-traffic " engines. For this purpose, as in Mr. Robinson's practice on the Great Central, by a judicious lessening of driving-wheel diameter, a very useful variant of the general design is obtained, capable of doing all that is required whilst preserving a very desirable measure of standardization of boiler and motion details. These 4—6—0 " mixed-traffic " engines are found in considerable numbers on the London and North-Western, the London and South-Western, the Great Central, the Caledonian, the Highland, the Great Southern and Western, &c., and are dealing most successfully with heavy loads which would be too much for the earlier " mixed-traffic " engines of the 4—4—0 type so common and so useful on the Great Eastern, the London and South-Western, and other lines.

0—8—0 Type.—Where increased haulage power has been the primary consideration, progress has naturally been along the lines of coupling up an additional pair of wheels, and we have the 0—8—0 engine as the result. The first British engine of this type was a single-expansion goods engine built in 1892 by Mr. Webb, and provided with a boiler 15 ft. 6 in. long fitted with a combustion chamber. The next year appeared the first of the three-cylinder compounds—also 0—8—0 goods engines—with modern boilers. In 1899 the Lancashire and Yorkshire followed with some powerful eight-coupled goods engines, and since that date the type has been freely multiplied and has become standard practice on all the " heavy " lines, except the Midland for the haulage of mineral trains, an additional pair of leading wheels (2—8—0 or " Consolidation " type) being added in the case of the Great Western and, to some extent, in that of the London and North-Western.

Boilers Common to Various Types.—Almost without exception the boiler adopted for use with these powerful mineral engines is similar to that employed for one or other of the large passenger engines. Thus the Great Western employ a No. 1 boiler with 14-ft.-10-in. barrel and 2142·91 sq. ft. of heating surface alike for 4—6—0 and 2—8—0 engines, whilst they also used the same boiler with the 4—4—2 type. The Lanca-

TABLE XVIII.—EXAMPLES OF ENGINES OF THE 0—8—0 AND 2—8—0 TYPES

Railway.	Date.	Boiler. Length.	Boiler. Diameter.	Working Pressure.	Grate Area.	Heating Surface. Tubes.	Heating Surface. Firebox.	Heating Surface. Total.	Cylinders. Diameter.	Cylinders. Stroke.	Diameter of Driving Wheels.	Adhesion Weight.	Remarks.
		ft. in.	ft. in.	lb. per sq. in.	sq. ft.	sq. ft.	sq. ft.	sq. ft.	in.	in.	ft. in.	tons cwt.	
London and North-Western (2—8—0)	1892	15 6	4 3	175	20.5	1120.8	153.8	1274.6	19½	24	4 5½	49 0	Combustion chamber.
	1893	15 6	4 3	175	20.5	1374	115	1489	15 (two) 30 (one)	24	4 5½	49 5	3-cylinder compounds.
	1905	15 6	4 6¾	200	20.5	1630	123	1753	15 (two) 20½ (two)	24	4 5½	53 10	4-cylinder compounds, rebuilt.
	1906	14 6	5 0¾	175	23.6	1979	146.75	2125.75	19½	24	4 5½	56 5	Converted 3-cylinder compounds.
(2—8—0)	1906	14 6	5 0¾	175	23.6	1979	146.75	2125.75	15 (two) 20½ (two)	24	4 5½	46 11	4-cylinder compounds, rebuilt.
Great Western (2—8—0)	1903	14 10	5 6 / 4 10¾	200	27.1	1988.65	154.26	2142.91	18	30	4 7½	61 18	Coned boiler.
Lancashire and Yorkshire	1899	15 0	4 10	175	26	1877	176	2053	20	26	4 5⅞	53 16	—
	1903	12 9	5 5¼	175	33	1882	135	2017	20	26	4 5⅞	57 19	Cylindrical firebox.
	1907	15 0	4 10	—	23	1767	147	1914	15½ (two) 22 (two)	26	4 5⅞	60 16	4-cylinder compound.
Great Northern ...	1901	14 8⅝	4 8	175	24.5	1302.1	136.74	1438.84	19¾	26	4 7½	54 12	—
	1913	16 0	5 6	170	27	1922	162	2654	21	28	4 8	65 8	—
Caledonian	1901	15 4	4 9½	175	23	2355	145	2500	21	26	4 6	62 10	—
North-Eastern ...	1901	15 0	4 9	200	21.9	1550	125	1675	20	26	4 7½	54 0	—
Great Central ...	1902	15 0	4 9½	180	23.6	1625	140	1765	19	26	4 7	61 5	—
Great Central (2—8—0)	1910	15 0	5 0	160	26	1538	153	1691 / 2009	21	26	4 8	66 0	—
Great Eastern ...	1906	12 11¾	4 9	180	22.9	1738.2	131.4	1869.6	18½	24	4 6	54 7	—
Hull and Barnsley ...	1907	14 0	5 6	200	22	1728	138	1866	19	26	4 6	61 11	—
Chicago, Rock Island, and Pacific (2—8—0)	1907	15 10¼	6 8	163	60.2	3658	179	3837	28	32	5 3	93 15	—

shire and Yorkshire "Atlantics" and the eight-coupled engines have boilers in common, as is also the case on the Great Northern so far as the earlier "Atlantics" are concerned. On the North-Eastern the boilers of the 4—6—0 and 0—8—0 engines are of practically identical dimensions, although differing in number and spacing of tubes. Mr. Robinson, on the Great Central, has a watchful eye on the possibilities of standardization, and has a 15-ft. boiler which, although in actual practice showing considerable variation in tube and firebox provision, could be readily fitted to several standard frames for differing wheel arrangements. On the London and North-Western, where the eight-coupled engine was first introduced, there are several classes of the type. In addition to the original simple engines built in 1892, and the three-cylinder compounds commenced the following year (now converted to two-cylinder simple engines), we have the four-cylinder compounds rebuilt as 2—8—0 engines, retaining their boilers, and those also rebuilt as 2—8—0 locomotives but provided with larger boilers. These conversions and rebuildings date from 1903.

Other 0—8—0 Engines.—Interesting recent examples of practice in 0—8—0 engines are afforded by the single locomotive of the type on the Great Eastern and the four-cylinder balanced compound class on the Lancashire and Yorkshire, both previously referred to, and the eight-coupled mineral engines which the increasing value of its coal traffic impelled the management of the Hull and Barnsley Railway to put to work between the colliery district and Goole and Hull. Appended are the leading dimensions of the chief classes of eight-coupled and "Consolidation" engines now running, an American example of the latter type being added for comparison; in American practice the leading truck is an almost indispensable portion of a design for freight locomotives, and the 0—8—0 type is almost without exception utilized for "switching" or shunting service.

2—8—0 "Consolidation" Type.—The Great Northern introduced a class of two-cylinder (21 in. by 28 in.) 2—8—0 engines, designed by Mr. Gresley, for working the heavy mineral trains over that system. These were followed by a series of three-cylinder (18 in. by 26 in.) engines of the same wheel arrangement. The boilers of the two classes are identical. The tractive force at 85 per cent boiler pressure is 32,605 lb. in the three-cylinder, as compared with 31,862 lb. in the two-cylinder.

The Great Central 2—8—0 engines—designed by Mr. Robinson, and adopted as a standard for service with the Railway Operating Division in France—have now been taken over by several of the British Railways, and are used mostly on heavy freight and mineral trains.

Besides two types on the Great Western, other examples of "Consolidation" engines are confined to the London and North-Western and Somerset and Dorset Joint.

Future Design in Goods Engines.—On the whole it would seem that design for goods and mineral engines in this country has now settled down on fairly well-defined lines, which are likely to endure for many years. That is to say, for ordinary goods traffic on lines not serving the mining

and manufacturing districts, the 0—6—0 type; for heavy mineral traffic the 2—6—0, 0—8—0, and 2—8—0 types; for express goods traffic the 2—6—0 and 4—6—0 types. Whether in course of time the demands of the traffic will lead to the introduction in this country of the ten-coupled engines, such as the American "decapod" type (2—10—0), is a question which the present writer does not propose to discuss. Looking, however, to what has been accomplished in the direction of increased haulage power of locomotives in this country during the past fifteen years, some such development is by no means impossible. The Midland Railway has recently built at Derby works a 0—10—0 banking engine for assisting heavy goods trains up the Lickey incline

CHAPTER V

Rail Motor-cars

The first modern British rail motor-car made its appearance about the year 1902 on the Fratton-Southsea section of the London and South-Western Railway—London Brighton and South Coast joint lines in the Portsmouth district. Since then there has been a large extension of the use of these cars and many interesting developments of the practice; but there is no doubt that there has been a growing conviction that rail-motor-car services have their limitations in usefulness, and several of the companies have been experimenting with a view to discover to what extent it is possible to develop this class of traffic not only with efficiency, but also with that measure of *economy* without which the advantages of the system quickly disappear. On this point one of the authorities was in no doubt.

In the course of his presidential address to the members of the Institution of Mechanical Engineers on 25th April, 1907, Mr. T. Hurry Riches, late locomotive superintendent of the Taff Vale Railway, one of the earliest lines to adopt the rail motor, said: "A great deal of controversy has arisen over this type, and, having had experience of it, I say that for sparsely populated districts, and indeed for close traffic in short distances, I look upon these self-contained cars as eminently successful; but when they are used to take trailer cars, and are in fact converted into mixed trains, then I think their advantages very soon disappear. Under such circumstances the method which is being adopted on the London and South-Western, and London Brighton and South Coast, and on some of the other railways, including the Taff Vale, of fitting carriages that can be attached to an ordinary locomotive, and by which arrangement that locomotive can be driven from the leading end of the carriage when it is being pushed in front, is the better method of dealing with mixed traffic." If this dictum of Mr. Hurry Riches is to be accepted as applicable in the case of lines other than his own, and

there are not wanting signs that such is the case, it would appear that the popularity of the rail-motor service has been its own undoing, for the system of attaching trailer cars, rejected by Mr. Riches, was the direct outcome of the large accession of traffic which the motor-car services with conveniently placed "haltes" soon brought to the companies instituting them.

"**Auto Trains.**"—As an alternative, some of the railways, including the Taff Vale, arranged services worked by small tank engines and carriages of ordinary type, so fitted as to enable the "train" to be worked from either end in the manner described by Mr. Riches, and whilst the earlier motor carriages were closely associated with the engine, it has in some cases become the custom latterly to facilitate interchange of units and the repair of parts by so arranging the vehicle that the engine can readily be run out from it and replaced at short notice. The management of the Dublin and South-Eastern Railway, Ireland, which in 1906 placed on its system two rail motor-cars of the usual design, operative from either the engine end or the other end, in 1907 detached the engines from the coach bodies, placing the latter on standard carriage bogies and running the engine round the car and its trailer so that it always heads the "train". This action, taken within twelve months of the institution of the service, constituting as it does a complete reversion of what was understood to be one of the leading principles of rail-motor working, viz. the avoidance of running around at terminals, shows that the lines upon which these services should be arranged are not very clearly defined. So much depends upon local circumstances that it is doubtful whether any general principles applicable to all cases can be laid down. At any rate we have, in addition to the slight use of petrol and electricity as motive agency, the following methods of steam working now in use in various parts of the country.

1. The rail motor pure and simple.
2. The same, with trailer car or cars attached, sometimes at both ends, capable of being worked as a unit from either extremity.
3. The "auto train" or ordinary tank engine, with carriages attached as above.
4. The same, the engine always running in front.

The more favoured practice is that indicated in Nos. 2 and 3.

It is, of course, possible that the future will bring interesting developments in the application of petrol and petrol-electric motors to rail cars. In view, however, of the greater elasticity of steam and the greater simplicity of the steam engine, it is doubtful whether the internal-combustion engine will ever make much headway.

Great Western Practice.—By far the most extensive user of rail motor-cars is the Great Western. On this railway there are upwards of forty distinct services on the system so worked, either exclusively or as supplemental to the ordinary train service. The cars are so allocated as to allow of the working being extended as required by the exigences of the traffic. Every variety of motor and "auto train" working is utilized;

every form of traffic is accommodated—rural, suburban, inter-urban, and tourist. This, in conjunction with the company's large fleet of *road* motor-cars—a feature of Great Western work outside the limits of these notes—forms the most perfect system of supplemental transport service at present organized by any railway company in the world, and supplies an excellent answer to the challenge of that competing transport working on the public roads so freely instituted of late years by municipal bodies and private companies. The rail motor services have also rendered it

A Modern Auto Train

possible to much improve the service between important towns on the system, as the train-stops can be fewer when a rail-motor service is available to serve the less important stations *en route*. Thus we find that, as in the Plymouth district, the rail motors work largely on lines radiating from some important centre.

What the largest of the British railways finds so profitable is also extensively used by one of the smallest. The total route mileage of the Taff Vale is only 124, but there is scarcely one of its numerous branches which is without its motor-car. Here, too, may be seen a typical instance of the alternative working referred to by Mr. Hurry Riches. In 1907 two " motor trains " were put into service, each consisting of one composite carriage and one third-class carriage, worked by a small locomotive placed between the two carriages, and so fitted that the train can be driven from the centre or either leading end. The total length of the " unit " is 166 ft. $1\frac{1}{2}$ in.

From the results obtained with these rail motor-cars it is plain that the hopes expressed in the conclusion arrived at by the International Railway Congress on this matter at the Washington meeting of 1905 are in a fair way to being realized. " It does not appear doubtful ", it was recorded, " that, owing to the saving of an employee in the driving, to the material reduction in the cost of traction, to the probable reduction in the cost of maintenance, to the better utilization of the rolling stock, to the smaller extent of station installations required, perhaps also owing to less wear of the rails, automobile and automotor cars will make it possible materially to reduce the cost of working lines with little traffic, and will in the case of other lines result in a material improvement in the working of some classes of service. Their use will certainly effect a change in the system of operation in the case of a great number of lines and appears to have a real future before it."

Rail Car Design.—In general design these rail motors are on much the same lines wherever found; indeed, when built by the railway companies themselves, a degree of standardization is being attained, resulting in considerable economy in first cost and facility in interchange of parts. There is, of course, considerable variation in internal arrangement of the cars, such as whether separate classes of passengers are accommodated, whether separate smoking compartments are provided, whether seats are arranged longitudinally or transversely, and so on. The vehicles of the Rhymney Railway may fairly be quoted as indicative of up-to-date practice in steam rail motors.

These cars are about 72 ft. long over all, and about 8 ft. 6 in. wide, the car body being 50 ft. $8\frac{1}{2}$ in. long and 7 ft. 6 in. high inside. The wheelbase is 55 ft. 10 in., the distance between the centre of the engine bogie and that of the car bogie at the other end of the vehicle being 47 ft. 7 in. The engine is detachable from the carriage portion of the vehicle, and has a coupled wheelbase of 8 ft. 6 in. A boiler, 4 ft. 6 in. in diameter, is provided with $1\frac{3}{4}$-in. tubes, and has a working pressure of 175 lb. per square inch. On each side of the boiler is placed a coal bunker, whilst 350 gall. of water are carried in each of the two cylindrical tanks suspended from the underframe of the coach. The four-coupled wheels are 3 ft. 6 in. in diameter. The interior of the car is divided into smoking and non-smoking compartments, accommodating sixty-four passengers in all. The car is entered at either end by means of drop-down steps worked by a lever. The lighting is by electricity. The usual duplicate driving and controlling gear is provided, so that the car can be worked from either end with equal facility, a remark which also applies to the braking, which is effected by means of the Westinghouse automatic quick-acting arrangement. More general use is at present being made of the short train of, say, engine and four coaches, in which the train may be worked from the footplate of the small tank engine in the centre, or from driver's compartments at either end of the train.

4—4—2 Express Engine, North British Railway

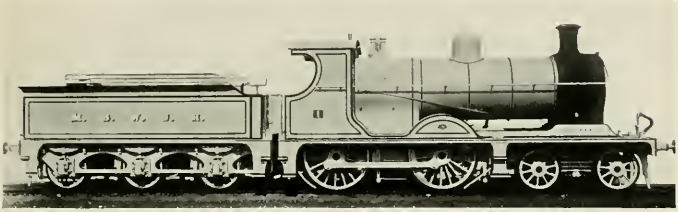
4—4—2 Express Engine, Lancashire and Yorkshire Railway

4—4—2 Express Engine "La France", Great Western Railway

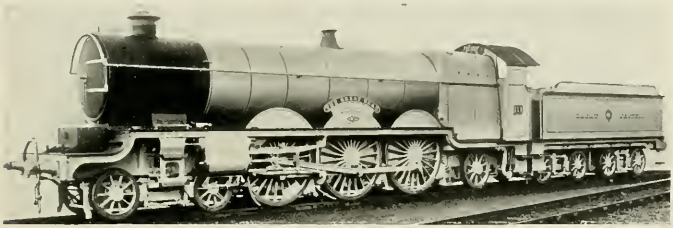
"County" Class Express Engine, Great Western Railway

"City" Class Express Engine, Great Western Railway

4—4—0 Express Engine, Midland Railway



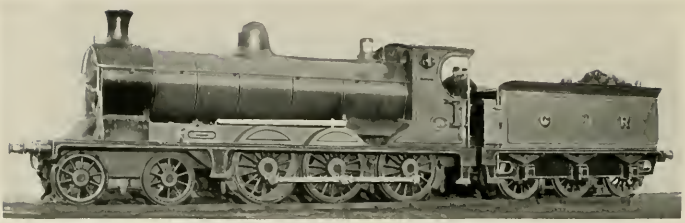
4—4—0 Express Engine, Midland and South Western Junction Railway



4—6—2 Express Engine "Great Bear", Great Western Railway

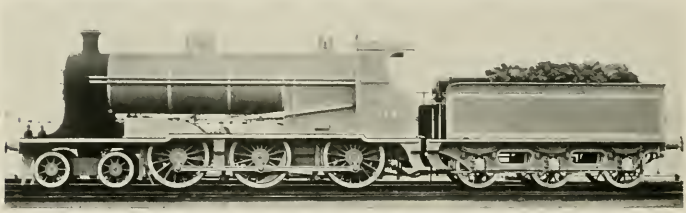
4—6—0 Express Engine, London and North Western Railway

4—6—0 Express Engine, London and South Western Railway

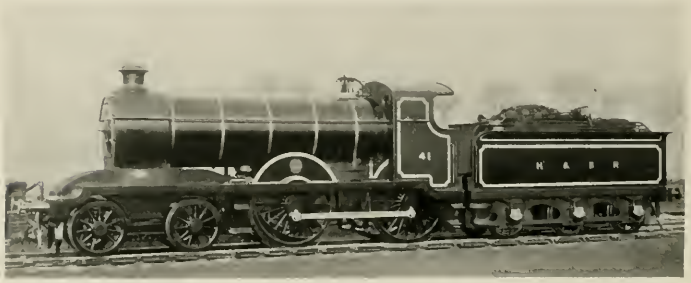


4—6—0 Express Passenger Engine, Caledonian Railway

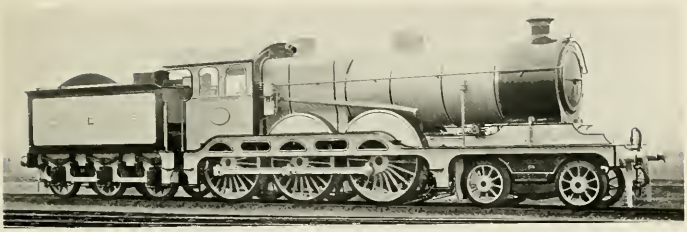
4—6—0 Express Passenger Engine, Glasgow and South Western Railway



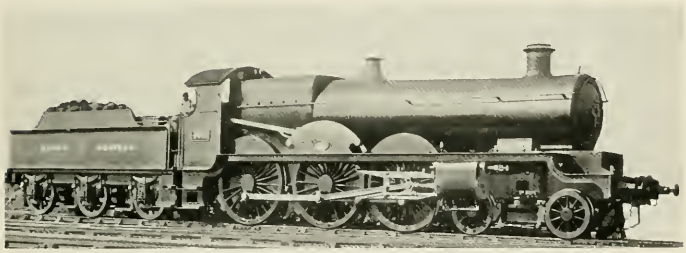
4—6—0 Express Passenger Engine, Great Southern and Western Railway



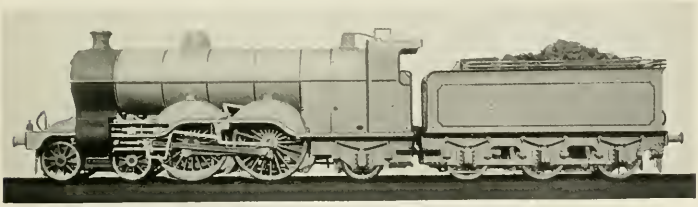
4—4—0 Express Passenger Engine, Hull and Barnsley Railway



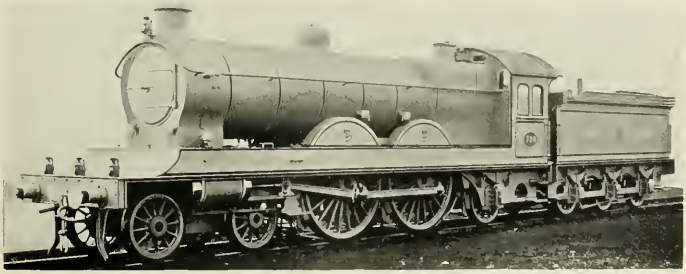
4—6—0 Express Engine, Great Eastern Railway



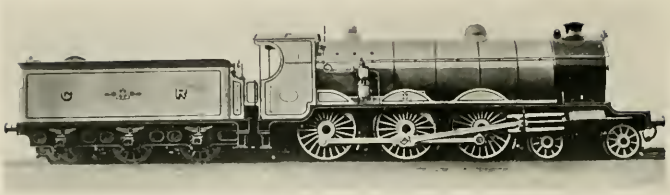
4—6—0 Express Engine, Great Western Railway



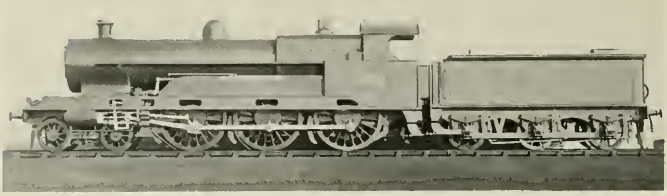
4—4—2 Express Engine, Great Northern Railway



4—4—2 Express Engine, North Eastern Railway

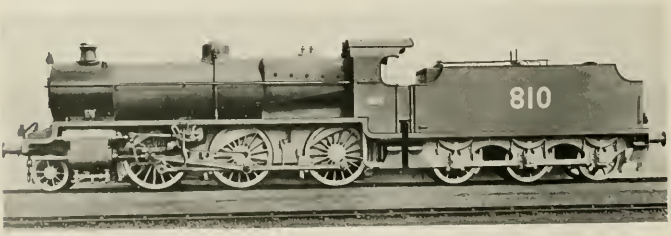


4—6—0 Express Engine, Caledonian Railway



4—6—0 Express Engine, London and North-Western Railway

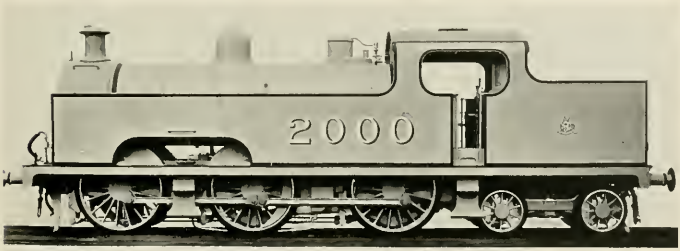
4—6—0 Express Engine, London and South-Western Railway



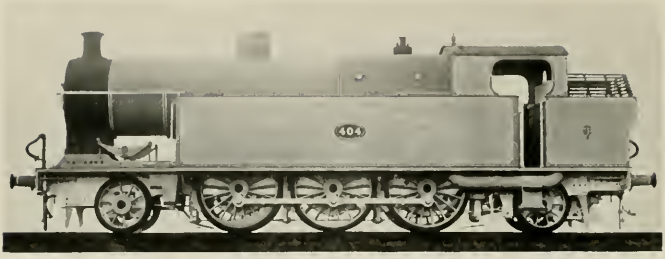
2—6—0 Passenger Engine, South-Eastern and Chatham Railway

4—6—2 Tank Engine, London Brighton and South Coast Railway

0—6—2 Tank Engine, London Brighton and South Coast Railway



0—6—4 Tank Engine, Midland Railway

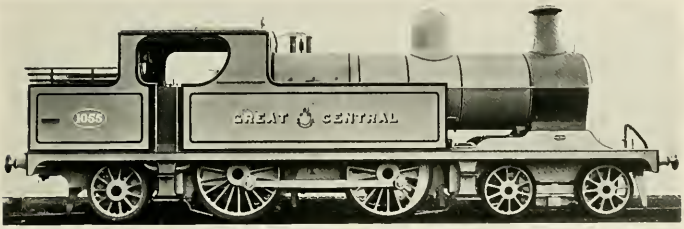


2—6—2 Tank Engine, Lancashire and Yorkshire Railway

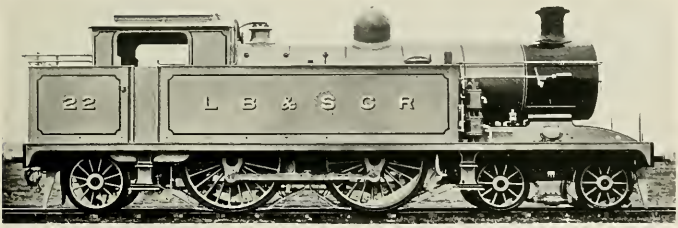
0—6—2 Tank Engine, Great Northern Railway

2—6—2 Tank Engine, Great Western Railway

2—4—2 Tank Engine, Barry Railway



4—4—2 Tank Engine, Great Central Railway



4—4—2 Tank Engine, London Brighton and South Coast Railway

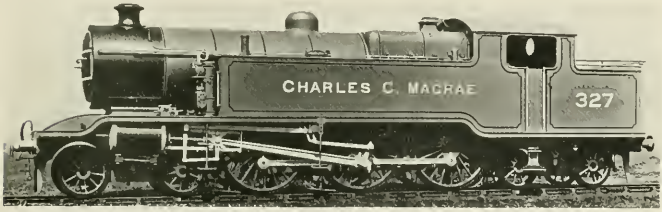
0—8—2 Tank Engine, Great Northern Railway

0—8—4 Tank Engine, Great Central Railway

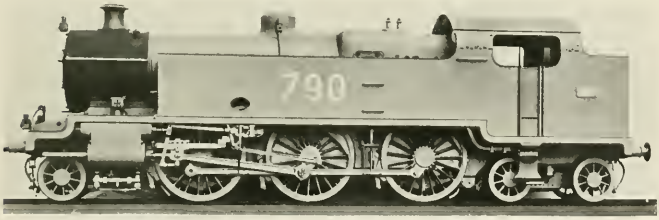
4—6—0 Tank Engine, North Eastern Railway

4—6—2 Tank Engine, Great Central Railway

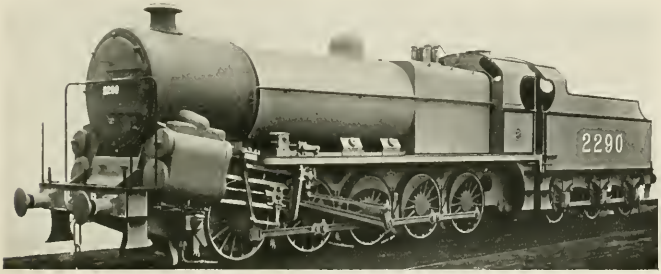
0—6—4 Tank Engine, Metropolitan Railway



4—6—4 Tank Engine, London Brighton and South Coast Railway

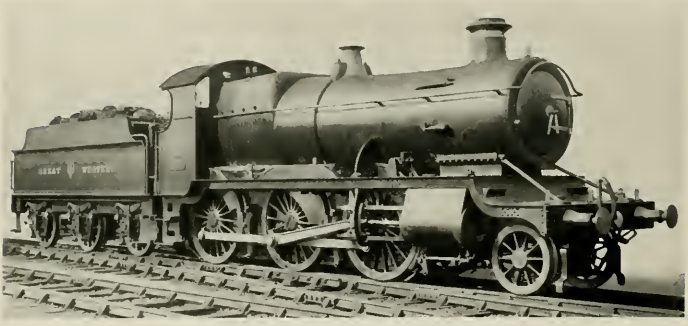


2—6—4 Tank Engine, South-Eastern and Chatham Railway



0—10—0 Banking Engine, Midland Railway

2—8—0 Goods Engine, Great Central Railway



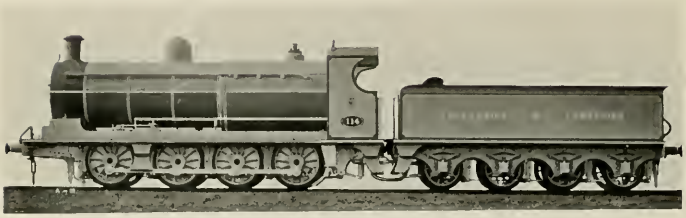
2—6—0 Goods Engine, Great Western Railway

4—6—0 Express Engine, Lancashire and Yorkshire Railway

0—6—0 Goods Engine, Midland Railway

0—6—0 Goods Engine, South Eastern and Chatham Railway

2—6—0 Goods Engine, Great Western Railway



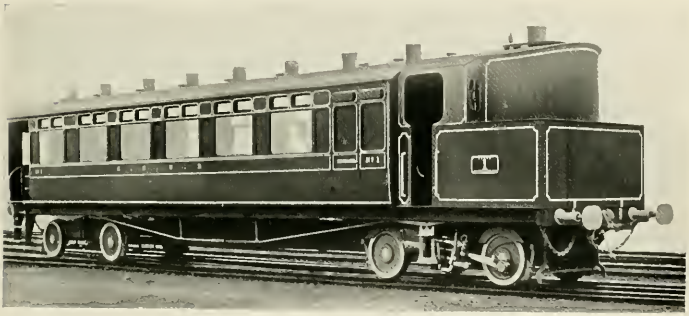
0—8—0 Goods Engine, Lancashire and Yorkshire Railway

0—8—0 Goods Engine, North Eastern Railway

Rail Motor Car, Great Northern Railway

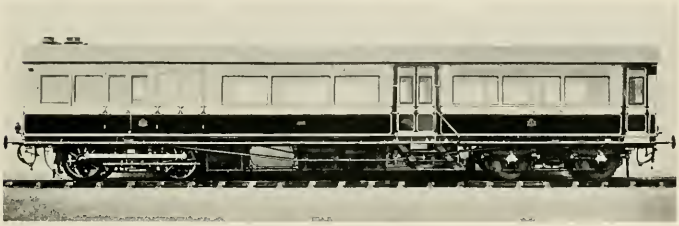
Rail Motor Car, Glasgow and South Western Railway

Steam Rail Car, Taff Vale Railway



Steam Rail Car, Great Southern and Western Railway

Steam Rail Car, Great Western Railway



Steam Rail Car, London and North Western Railway

THE DESIGN AND CONSTRUCTION OF CARRIAGES AND WAGONS

BY

S. WARNER

(Carriage and Wagon Superintendent, London and South-Western Railway)

The author desires to acknowledge with thanks the help rendered him during the preparation of this article by Mr. A. A. Shepherd, Chief Assistant and Works Manager, Carriage and Wagon Department, Eastleigh.

The Design and Construction of Carriages and Wagons

CHAPTER I

Introductory and General

In the present article, owing on the one hand to the necessary limitations of space, and on the other to the great variety of stock and the very wide scope of the subject, it has been found impossible to go into such full details of the design and construction of carriages and wagons as one might have desired. Nevertheless, while it deals for the most part with main facts and general principles, it has been written with sufficient breadth of treatment and detail to make it a comprehensive treatise on present-day practice. As a contribution upon a highly technical subject would be of little practical value without numerous illustrations, as many as possible have been given, but it should be understood that they are by no means exhaustive, and have been mainly chosen to represent fairly such types of stock and details as would be met with in average practice in the United Kingdom.

Rolling Stock and a Reminiscence.—Great progress has been made both in the design and construction of rolling stock during the past decade, and the present-day third-class passenger enjoys accommodation almost equal to the first-class of a few years ago. Second-class carriages have been abolished on many lines and are rapidly becoming extinct.

Although the article will be found to deal only with modern vehicles, the illustrations of some of the earliest examples of British rolling stock (see Plate I) will be of interest to readers. This stock was actually in use until about thirty years ago. The composite carriage illustrated is now on exhibition at Waterloo Station, London, standing on a piece of the actual permanent way it ran on when in service. Other passenger vehicles are still carefully preserved at Eastleigh Works, and models to scale of two of them may be seen at South Kensington Museum. These vehicles formed part of the stock of the Bodmin and Wadebridge Railway in Cornwall, and although the line, which was opened about the year 1836, was of the present standard, 4 ft. $8\frac{1}{2}$ in. gauge, and about $6\frac{1}{2}$ miles long, it was isolated for any

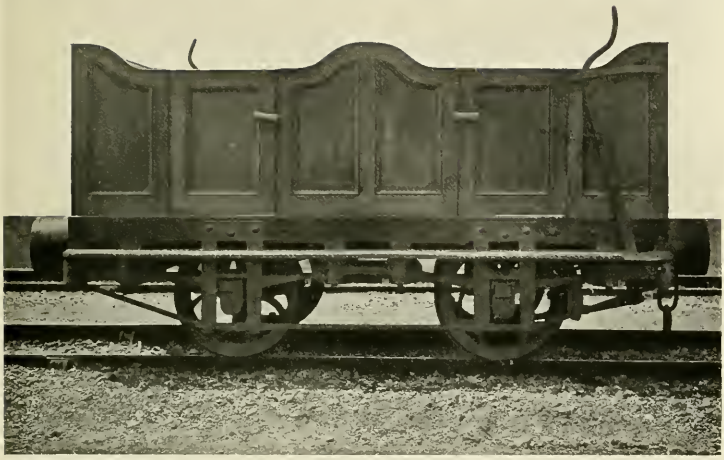
through traffic until the broad gauge of the Great Western Railway Company was altered over fifty years afterwards. Exactly when and by whom the stock was made is not known, but quite probably it was made in the locality, and although it is all supposed to have been built about the date the line was opened, it is likely that the covered vehicles were of a little later date. The train ran about twice a week each way, and in the early days it is said that the general manager would start the train at one terminus, and then *drive* over and attend to it on its arrival at the other. This may quite possibly be true when it is considered that there were no signals on the line, and only the two terminal stations, and the trains stopped at any point when required. The couplings were loose chains, and the buffers simply shaped blocks of wood, so that the operation of starting and stopping must have been " shockingly " apparent to the passenger. Appended to the illustrations are interesting particulars of the dimensions, &c. This line was taken over by the London and South-Western Railway Company in 1886, and ultimately reconstructed, and now forms with Padstow the most westerly branch of the system.

Wide Range of Carriage Construction.—No attempt has been made to deal fully with the workshop practice of all the trades and branches of this work, but sufficient information has been given on the principal parts, i.e. bodies and underframes, to give a student or general reader useful information on the subject. The portion dealing with road vans will also be found to contain some useful particulars of workshop practice.

The machinery and power equipment of a modern carriage and wagon works would require considerable description and illustration, and is of course beyond the scope of this article; but it may be stated that recent years have produced great improvements in this direction, and that steam, oil, and gas, electricity, hydraulics, and pneumatics have been utilized to the fullest extent to produce the work as cheaply as possible.

To illustrate the variety of work in this branch of the railway service, it may be mentioned that the following occupations are employed therein, exclusive of the supervising staff, inspectors, clerks, &c., and although many of these are recognized trades, the men employed in some would be more correctly considered as skilled labourers, and, with the development of machinery just referred to, the latter are steadily becoming more numerous: bodymakers, carriagemakers, wagonmakers, millwrights, fitters, finishers or cabinetmakers, painters, trimmers, smiths, forgemen, patternmakers, moulders, electricians, wiremen, gasfitters, tinsmiths, plumbers, brassfinishers, brakefitters, turners, toolmakers, drillers, riveters, holders-up, polishers, lifters, writers, grainers, glaziers, saddlers, liningmakers, carpenters, machinists, grinders, wheelmakers, strikers, sawyers, springmakers, springtesters, woodturners, tyremen, gasmakers, furnacemen, locksmiths, train examiners, greasers, oilers, and labourers.

There are no statistics available of this important industry which give exactly the number of men directly employed in the United Kingdom in the construction and repair of railway carriages and wagons, and the number



THIRD CLASS BRAKE

Length, 10 ft.; width, 6 ft. 4½in.; height above rails, 5 ft. 5 in.; wheel base, 4 ft. 6 in.; weight, 1 ton 19 cwt.

COMPOSITE CARRIAGE

Length, 14 ft.; width, 6 ft. 6½ in.; height above rails, 8 ft. 5 in.; wheel base, 7 ft. 6 in.; weight, 3 tons 5 cwt.

EARLY TYPES OF RAILWAY CARRIAGES

Bodmin and Wadebridge Railway. About 1835

fluctuates in proportion as trade is good or bad; but it may be estimated that considerably over one hundred and fifty thousand men and youths are regularly so employed, and a large number of women (in the trimming and polishing departments), and, of course, many thousands indirectly in the manufacture of the miscellaneous articles used in the construction of rolling stock, as well as many in the timber trade. The latter is considerably affected by the state of this department of railway work. The building of rolling stock for export has somewhat decreased in recent years, due to many of the foreign and colonial lines having built workshops to carry out the construction themselves, but there is still an extensive export trade done, the work being principally carried out in the " contract shops " of the Midlands and North of England.

The Comfort of the Passengers.—Perhaps the most important feature of modern carriage construction in Britain is the increasing adoption of corridor carriages by all the leading lines. These are mostly of the side-corridor type, and as the seating accommodation is from 20 to 30 per cent less than in ordinary vehicles, and the weight 10 to 20 per cent more, trains are much heavier and longer in proportion to the passengers carried than formerly. It must also be added that corridor stock involves an increase of about 25 per cent in first cost.

The writer believes that dining-cars were first used in a regular service by the Midland Railway in 1888, but entire trains with through corridors, enabling passengers to have access to the " diners " from any part of the train, did not become general until some years later, and their extensive adoption for comparatively short journeys is quite recent, and an indication that the public appreciates the facilities afforded. From a passenger's point of view another excellent improvement, and one which gives a sense of security when travelling, was the adoption by all companies of an effective system of communication between passengers and the guard and driver in connection with the power brakes; and although but a few years have elapsed since the completion of this work, it now seems scarcely credible that the crude arrangement of a cord carried along *outside* the carriage cornice should have remained in general use for over twenty-five years.

Owing to the number of accidents arising to passengers (principally children) through falling out of trains in motion, a very large number of patents have been granted in recent years for devices to lock additionally and automatically the carriage doors whilst the vehicles are travelling, but up to the present, however, none has met with adoption. It is extremely doubtful whether the public generally would approve of being locked in compartments under all the conditions that might arise when travelling, and many accidents would undoubtedly be avoided if children were warned, not only by their parents, but at schools, not to play with the inside door handles when in trains. Although locks with inside handles are a great convenience to passengers, particularly on suburban lines when stoppages are of short duration, and on wet days, obviating the necessity of lowering the window to open the door, it is necessary to explain why they are very

undesirable for carriages with side corridors, inasmuch as at night-time when the trains are lighted the reflection on the outside windows of the corridor side may easily mislead a person who, awaking from sleep, wishes to go into the corridor, causing him to open the outside door and instantly to fall out. That an accident arising from a defective lock is extremely rare, shows that no expense is spared to fit the best locks obtainable, and to maintain them in good working order.

The Battle of the Brakes.—The chapter on continuous brakes is mainly illustrated by drawings and descriptions taken from official sources; and although space would not permit of going into the many devices recently introduced for trial in connection therewith, it can be stated that every effort is being made to give all possible security to the traveller in the matter of brakes. It will probably be of interest to the reader to recall the circumstances leading to the adoption of continuous brakes in Britain. It is now nearly forty years ago since they were first fitted here, but it was not until 1889 that their use became obligatory by Act of Parliament, as a result of the terrible accident at Armagh in the early part of that year. This accident arose through the running away backwards down an incline of the rear portion of a crowded excursion train which had been divided, as the engine was not powerful enough to negotiate the bank with the whole load. The engineless, brakeless vehicles started off by themselves, and when they had attained terrific velocity they collided with another train following behind. In the smash that ensued, 80 persons were killed and 400 injured.

That, in conforming to the Act of Parliament, some companies adopted the Westinghouse system and some the vacuum automatic is so well known as hardly to need recapitulation and lament; but as little interchange of passenger stock was then in vogue, and daily through carriages over many lines not thought of, it could not be foreseen that this action would entail heavy expense on the companies in the years to come. To the general reader it may be explained that this expense is incurred by having to equip sufficient stock (both carriages and wagons) with both brakes in order to carry on the through traffic which is yearly increasing, and that this equipment, apart from the cost and extra weight, necessarily causes complication of the braking gear. Roughly, the proportion of vacuum fitted vehicles to Westinghouse fitted is 2·7 to 1, so that if one system were adopted generally the conversion of the Westinghouse fitted stock would obviously entail the least expenditure, but there are other points which require careful consideration. The problem is a complicated and big one, but in the interest of ultimate economy it will sooner or later have to be faced. The grouping of railways will probably hasten the time when only one system will be in operation.

Much discussion has taken place in engineering and other papers as to the efficiency of the vacuum brake (prompted no doubt by the serious derailments a few years ago on curves), and an accident of any magnitude under such conditions invariably produces a number of suggestions as to the failure of the brake, due to the supposed displacement of the ball in the valve owing

to centrifugal force, or the supposed inefficiency of the indiarubber piston ring, &c. It is satisfactory to know that many exhaustive experiments and tests have been carried out on these points, and there is no probability whatever of centrifugal force acting on the ball valve on a curve to such an extent as to cause displacement, and that in the latest cylinders with which recently constructed carriages are fitted, the retention of the vacuum is not dependent upon the position of the ball in the vertical valve fitted within the cylinder. Again, the indiarubber rolling ring has proved (taking the enormous number in use) to be very reliable and efficient for its work, and not at all likely to cause a serious mishap.

The point sometimes raised, and one which is certainly liable to cause inefficiency of the brake by loss of power (see tabulated statement in Chapter IX), is the excessive stroke of the piston when the brake is applied, due to want of timely adjustment in the gear for the wear of the blocks; and although all companies using the vacuum system give particular attention to this point, the necessity for doing so cannot be too often impressed upon those responsible for this work. Automatic adjustors (or tooth-geared pickups) have recently been experimented with for this purpose, and although great improvements have been made therein, the rough and dirty conditions under which these have to work render the introduction of any mechanical arrangement a very difficult problem to deal with, as unless efficiency can be maintained at all times no general adoption thereof could be recommended. It has been frequently suggested that by the introduction of an auxiliary vacuum chamber an increased stroke of piston might be safely permitted; and further, that there would be considerable advantage derived therefrom if at any time a low vacuum was used. This suggestion is a good one, and is now being brought into general use on all new heavy stock, although of course entailing increased expenditure of steam and a longer time in re-creating the vacuum when destroyed. In recent years considerable improvements have been made in the ejectors, not only enabling the necessary vacuum to be more quickly obtained, but to ensure an average of over 20 in. being maintained whilst running.

Loading Gauges.—The great variation in the maximum loading gauges of the different lines in England, Scotland, and Wales becomes increasingly troublesome as years go on and through traffic increases, as it limits the building of the through rolling stock in many cases to dimensions to suit the minimum gauge; and, further, requires considerable care to be taken by the staff so that only suitable vehicles are loaded with through traffic. The particulars on p. 92 will aid in making this point more clear, and perhaps it is not too much to hope that, now standardization in many ways is being effected, some modification may in course of time be carried out in the smaller gauges.

At the time of writing this matter is under careful consideration, but the enormous expenditure involved makes the adoption of a uniform loading gauge very improbable for many years to come. The best that can be hoped for is a gradual improvement up to the largest.

COMPARISON OF MAXIMUM LOADING GAUGES (GREAT BRITAIN)

	Feet.	Inches.
Minimum in height (at centre)	12	4
Maximum ,, ,, ...	13	9
Minimum ,, (at sides)	10	0
Maximum ,, ,, ...	12	0
Minimum in width at 6 ft. from rail level	8	10
Maximum ,, ,, ,, ...	9	8
Minimum ,, 2 ft. ,, ...	7	10½
Maximum ,, ,, ,, ...	9	0

Cost of Rolling Stock.—A few words on the financial side of this industry will serve to confirm the opening paragraphs of the chapter on wagons. Prior to the war the average wagon cost from £2 to £2, 10*s.* per annum to maintain, and the average passenger carriage from £20 to £30, but these figures require to be increased from 200 to 300 per cent at the present time. If we take into consideration the approximate costs and quantities of stock as given in the tables which follow, we may see with little calculation the enormous capital represented by the rolling stock of the United Kingdom (exclusive of locomotives) and the vast amount necessary to be expended for its maintenance.

The costs when new of the several types of vehicles will necessarily be subject to the fluctuations of the market prices of the materials used and the current cost of labour. Again, these figures, for either costs or weights, differ somewhat in all companies, in consequence of the variety in the details, and also the amount of work put into the manufacture and construction. The prices given below do not apply to any particular company's stock, and are quoted only as a guide to students and others as to the cost of such vehicles in general.

Description of Vehicle.	Weight (about) in Tons.	Cost (about) when new in £ (1913).	Cost (about) when new in £ (1921).
Corridor composite	28	1200	3600
Third class and brake	25½	800	2400
Dining car	32	1450	4350
Sleeping-saloon	30	1500	4500
Invalid saloon	23	1000	3000
Milk van	13	450	1350
Family saloon	25½	970	2910
10-ton wagon (private owner) ...	6	70	210
Covered goods	8¼	140	420
Cattle wagon	8	110	330
Timber truck	5	75	225
Rail wagon (40 ton)	17½	300	900
Ballast wagon (40 ton)	17	350	1050
Refrigerator van	9¼	200	600
Goods brake van	21	250	750
Horsebox	9¾	270	810

The following particulars of the quantities of railway rolling stock in Great Britain and Ireland are taken from the advance figures for the official returns for the year 1920. Wagons privately owned are not included in the figures given, but on 1st August, 1918, there were 628,344 such wagons [1] registered to run on the railways of Great Britain.

I. England and Wales

1.	Total number of rail motor carriages (steam)	130
2.	,, ,, (electric)	1,342
3.	,, carriages used for the conveyance of passengers only	43,996
4.	,, other vehicles used on passenger trains	17,726
5.	,, wagons of all kinds used for the conveyance of live stock, minerals, or general merchandise (including brake vans)	608,656
6.	,, railway service vehicles	44,141
	Total	715,991

II. Scotland

1.	Total number of rail motor carriages (steam)	3
2.	,, ,, (electric)	*nil*
3.	,, carriages used for the conveyance of passengers only	6,725
4.	,, other vehicles used on passenger trains	3,194
5.	,, wagons of all kinds used for the conveyance of live stock, minerals, or general merchandise (including brake vans)	133,724
6.	,, railway service vehicles	5,064
	Total	148,710

III. Ireland

1.	Total number of rail motor carriages (steam)	3
2.	,, ,, (electric)	13
3.	,, carriages used for the conveyance of passengers only	2,111
4.	,, other vehicles used on passenger trains	1,207
5.	,, wagons of all kinds used for the conveyance of live stock, minerals, or general merchandise (including brake vans)	23,062
6.	,, railway service vehicles	1,748
	Total	28,144

Grand total of vehicles (exclusive of locomotives) owned by railway companies (exclusive of Manchester Ship Canal) in England, Wales, Scotland, and Ireland, 892,845.

[1] Board of Trade Census.

CHAPTER II

Timber

In this article the timbers used in carriage and wagon building are divided into two varieties—those employed in construction and those in finishing and decoration. The timbers chiefly used in construction are oak, teak, pitch pine, mahogany (outside panel), red and white deals, jarrah, karri, and ash. Those for decorative purposes: walnut, mahogany (figured), wainscot oak, sycamore, satinwood, bird's-eye maple, Hungarian ash, and birch (three-ply).

Oak.—The principal timber used is oak, of which there are several species, but those used mostly are English, American, and Stettin or Dantzig. English oak is the strongest and most durable of these, but, owing to its scarcity in any length or size, it is seldom used for carriages, although some builders still use it considerably for wagons and short vehicles.

There are many varieties of American oak, but the best is that known as American white oak, the finest trees being found in Maryland. These trees grow in the forests to a height of 50 to 60 ft. clear of branches, and allow of fine logs from 45 ft. and up to be imported at about 18 in. square. Until recently this timber was used very extensively in carriage building, as when the carriages were 40 to 50 ft. long, good clean scantling of this length was to be got; but of late years, owing to the lengthening of cars to 56, 60, 65, and 70 ft., no scantling of any kind can be got this length, and splicing has had to be resorted to, and Stettin oak has to a great extent superseded the American. This American oak is not so tough as English, but, owing to its straight grain, lends itself to bending.

Stettin oak comes from Poland, but takes its name from the port from which it is exported. Some of it is shipped at Dantzig, and is sometimes called Dantzig oak, but it is grown in the same district. Oak grown in neighbouring districts is now taken by rail to Odessa and shipped from there. This oak is of the same nature as Stettin and Dantzig, but has the advantage of having no nails in it, as it is taken by rail and not floated down by river, as in the case of the others.

All these several oaks shrink in seasoning, and require keeping in plank for some time after cutting. A year for an inch in thickness has been found a good rule.

Teak.—Teak is used a great deal in the construction of carriages. Although much more expensive than oak, it does not require to be kept so long, as it shrinks very little in seasoning. It is strong, hard, and easily worked, but not so tough as oak. It contains a resinous oil, and is somewhat gritty, which spoils the edges of the tools in working it, and it does not take paint well. The best qualities of teak are those from Moulmein, Rangoon, and Bangkok, although a quantity is now imported from Java.

Pitch Pine.—Pitch pine is used very little in carriage construction, its chief use being for step boards. It is shipped from the southern states

of North America, the best shipments being from Pensacola. It is imported in hewn and sawn logs, the latter 45 to 50 ft. long and 18 to 20 in. square, and the former from 20 to 40 ft. long and 9 to 14 in. square. The wood is of a reddish-white colour, and is clean, hard, highly resinous, and straight in the grain. It is hard to work, but durable and strong. Underframes of wagons have been built of this timber with good results. Sometimes logs are found from which finely figured boards can be obtained, and some of this is very handsome.

Mahogany.—Mahogany is utilized mostly in panelling up the outsides of coaches. The best qualities come from Central America and Mexico, but latterly, owing to the great demand, a good deal of African is being used.

Mahogany is strong, tough, and does not shrink much. Care should be taken that the seasoning does not take place too rapidly. Mahogany is also used for decorative purposes, and the figured logs from Cuba are very handsome.

White and Red Fir.—Spruce or white fir is used in carriage construction in boards, mostly for partitions. It is white in colour, and frequently hard knots are found in it. It is not so durable as the red fir, and is generally used where not exposed to weather. It is principally imported from Norway. Red fir is employed usually in boards for flooring and roofing in carriage construction, and for sheeting and flooring of wagons as deals or battens. This timber is generally sold as deals and battens, a deal being 9 in. and up wide, whilst a batten is 7 in. wide and less.

Jarrah and Karri.—These woods belong to the Eucalyptus family, and are imported from Australia. They are very hard and close-grained, but very heavy. They are used by some builders for wagon solebars and headstocks, but owing to their weight they increase the tare. They can be used in goods brake vans with good results where weight is required.

Decorative Woods.—Usually the black American walnut is used in carriage construction. It is rather plain in grain, but looks well when worked up with sycamore and satinwood.

Sycamore is grown in most parts of Britain, and the south of Europe. It is very white when good, and is used largely in saloons, &c., for inside panels.

Hungarian ash is a finely figured wood, and is used for inside panels and decorative work.

Wainscot oak comes from Riga. It is very nicely figured when cut in the direction of the medullary rays.

Satinwood is a fine, hard, close-grained wood, showing on its polished surface a beautifully rippled pattern, and is grown in South America and India. Being now comparatively scarce, and consequently expensive, it is used principally as veneers for panels of saloons and first-class compartments.

Seasoning.—There have been a great many new methods of seasoning timber quickly by artificial means, but up to the present none of them has proved so good as the natural process. This requires a good drying shed,

well ventilated, to allow currents of air to pass through freely. The boards or planks should have strips placed between them about ½ in. thick, to keep them apart and allow the air to get at them.

The weight of timber is very difficult to estimate accurately, as it varies very much. Pieces from the same log often differ, and the amount of seasoning they have had also affects the weight. The following are the approximate weights of timber used in the construction of rolling stock:

English oak	.. .. ..	50–54 lb.	per cubic foot.
Stettin oak	.. .. ..	48–52	,, ,,
American oak	.. .. ..	47–50	,, ,,
Jarrah	.. ..	60–64	,, ,,
Teak	.. ..	44–46	,, ,,
Mahogany (panel)	.. ..	35	,, ,,
White deal	.. .. ..	30	,, ,,
Red deal	.. .. ..	33	,, ,,
Pitch pine	.. .. ..	38–42	,, ,,
Walnut	.. ..	43	,, ,,

A simple formula for finding the approximate cubic contents of a log is as follows:

$$\text{Cubic contents in feet} = \frac{\text{mean quarter girth in inches}^2}{163} \times \text{length in feet.}$$

(NOTE.—The division by 163 instead of 144 makes allowance for the bark.)

The following information relating to deals and battens is very useful, and is appended for reference.

A Petersburg standard of deals contains 165 c. ft.

One standard is	1358	ft. run of	7	in. by	2½	in.
,,	1131	,,	7	,,	3	,,
,,	880	,,	9	,,	3	,,
,,	720	,,	11	,,	3	,,

One load of unhewn timber is 40 c. ft.
,, squared ,, 50 ,,

CHAPTER III

Underframes

In considering modern practice with regard to railway-carriage underframes, it will be necessary—although bogie vehicles form by far the larger proportion of coaching stock—to include both four- and six-wheeled frames; as, although the latter are not built anything like so extensively as in the past, they are still a necessity for horse boxes, luggage vans, carriage trucks, milk vans, &c., and are still used for suburban and branch trains.

The four-wheeled stock varies in length from 16 to 26 ft., and six-wheeled coaches from 28 to 37 ft., with wheel bases which, on the average, will be found to be approximately two-thirds of the length of the vehicles. Carriages with flexible wheel bases are now built from 40 to 70 ft. in length; and in recent years the tendency has been to build as long as possible, consistent with the length of the permanent-way locking bars, and at the same time to retain the four-wheeled bogie in preference to the six-wheeled truck, due to the latter requiring considerably more haulage. To give an example of this, mention may be made of the large number of 70-ft. vehicles built by the Great Western Company; these were equipped with four-wheeled bogies, some having a 9-ft. wheel base and others 10 ft., the journals and axles of which were made correspondingly larger, to take the increased load. An illustration of the underframes of these vehicles will be given and described at the end of this chapter.

At the present time general opinion favours, for passenger-carrying vehicles, the construction of coaches of from 54 to 58 ft. in length, and carried on two four-wheeled bogies, each having a wheel base of about 9 ft., with the centres varying from 38 to 41 ft. apart; and it is probable, with the British standard 33 ft. length of locking bars, and the many curves ranging from 5 to 10 chains radius on the existing main lines of permanent way, that this will remain a general practice for some considerable time.

Determining Factors in Underframe Design.—The designing of modern underframes is largely dependent upon the fittings they have to carry, as the constant additions to undergear to suit dual brakes, gas, electric light, and steam heating have rendered it imperative not only to make the frames sufficiently strong to support the bodies and also to stand the ordinary strains of use in traffic, but to have a large factor of safety for taking the strains from the brakes, draw and buffing gear, and the great weights suspended, as in the case of dynamos, accumulator boxes, &c. It is generally admitted that for these reasons, in designing all the parts of underframes, theoretical calculations have proved of little value, and the modern frame is undoubtedly the outcome of many years of practical experience. In designing trusses for the solebars of long carriages, however, some assistance may be derived by using the well-known graphic diagram for the construction of the queen-post truss, this form of truss being by far the best for use on long vehicles.

A general rule for trussed girders is to make the depth of the strut from one-eighth to a twelfth of the total span, but this rule in railway carriage work is necessarily subservient to the fixed height of the top of the solebars above rail level (about 4 ft.), and to the adequate clearance that must be given for the bogie end to radiate clear of the truss rod when traversing curves. This matter will be briefly further referred to later in the description and illustration of a modern underframe for a bogie carriage, but it may be stated that the average ratio of the depth of truss to the span in British rolling stock is approximately as 1 is to 20.

British practice is to build the underframe and bodies quite distinct,

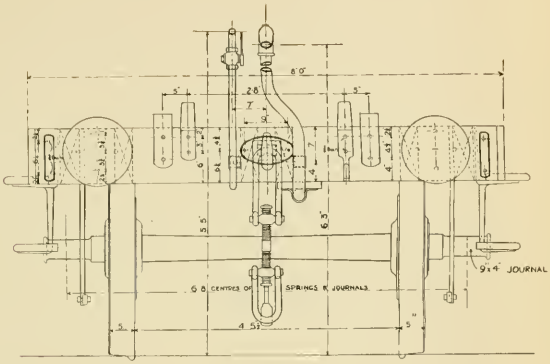
the latter being bolted down to the former, having 1-in.-thick packings of indiarubber, or other suitable material, about 8 in. long, placed between at intervals of about 6 ft. These holding-down bolts should be placed as near the doorway standing pillars as may be convenient. Building the bodies separately, however, is not a hard-and-fast rule, as several vehicles have recently been constructed on similar lines to the American design, with the floors resting directly on the underframe members, in which case no body bottomsides are used, the side sills taking the place of both bottomsides and solebars, as used in British practice.

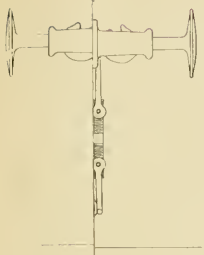
Design of Four-wheeled Underframes.—In four- and six-wheeled carriages the solebars may, for all practical purposes, be considered as through girders, carrying a load at fixed points, i.e. the positions of the scroll irons—and in bogie vehicles the solebars are supported at two points only—corresponding to the bogie centres, the overhanging cantilever ends being free and carrying a distributed load.

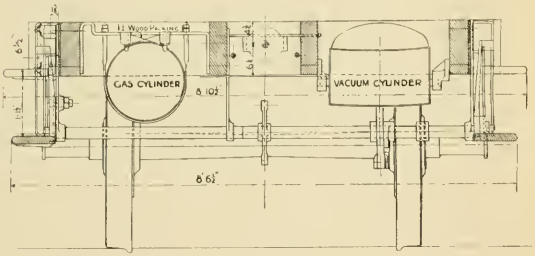
The first illustration of an underframe is that of a 21-ft. horse box (see Plate II), and may be considered as typical of all four-wheeled frames. In this instance the solebars are of American oak, 11 in. deep by 4 in. thickness, with 11-by-$\frac{3}{8}$-in. mild steel plates, and all the short members of Stettin oak. Although some companies use steel entirely for frames of similar length, it is now generally conceded, from a maintenance point of view, that wood frames are more economical, and it may be acknowledged (although good reasons have been advanced for the change) fashion in a measure often does affect even the builders of railway rolling stock, inasmuch as a few years ago a very large percentage of short underframes were constructed entirely of iron or steel, while at the present time oak is being again extensively used, particularly for the underframes of wagons. From the illustration of the horse-box underframe it will be seen that it has a continuous drawgear, with laminated buffing and draw springs composed of fourteen plates 3 in. by $\frac{7}{16}$ in. steel, having an initial compression of 6 in., equivalent to a load of $2\frac{1}{2}$ tons.

It is fitted with both Westinghouse and vacuum brakes, and the hand-brake arranged with the actuating levers both right-handed, so as to conform to the now adopted regulations of the Board of Trade. All the frame members are well tied together with knees and rods, and as the drawing is dimensioned little description is necessary beyond explaining that the buffers and drawgear are placed out of the centre of the frame, owing to the necessity of keeping the cornice of the horsebox within the "loading gauge". A comparison of the British maximum and minimum gauges is given in Chapter I. A short account of the workshop practice in the preparation of the various members may be useful.

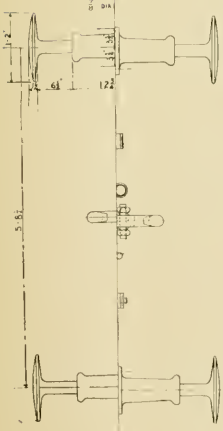
The timber for the solebars is delivered in logs, which, after thorough inspection, are cut to size by the log frame saw, sufficient material being allowed for planing up and the inevitable shrinkage. The interior parts are generally delivered in scantlings of required sizes, and these and the solebars are planed up by machine to the finished size. The positions

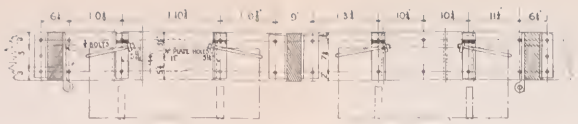


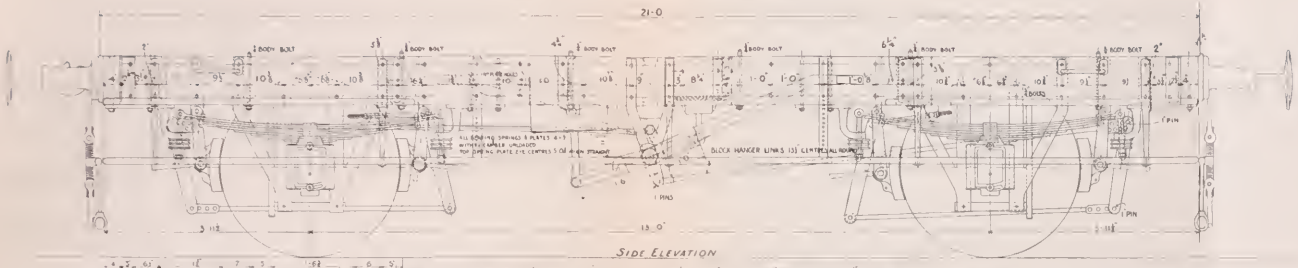


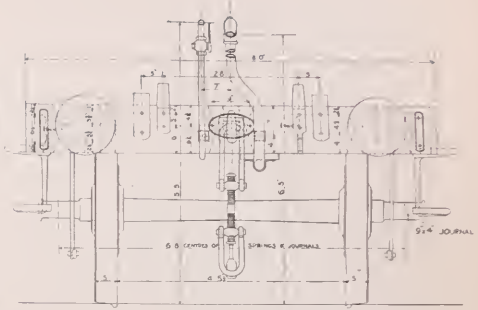


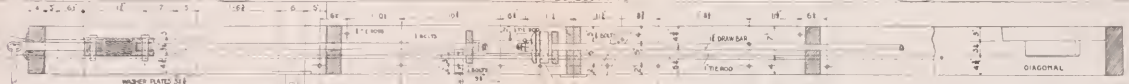
CROSS SECTION

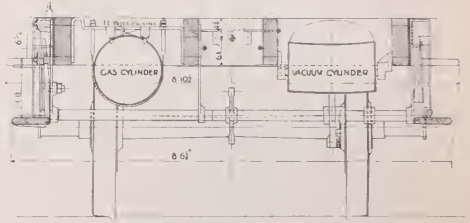


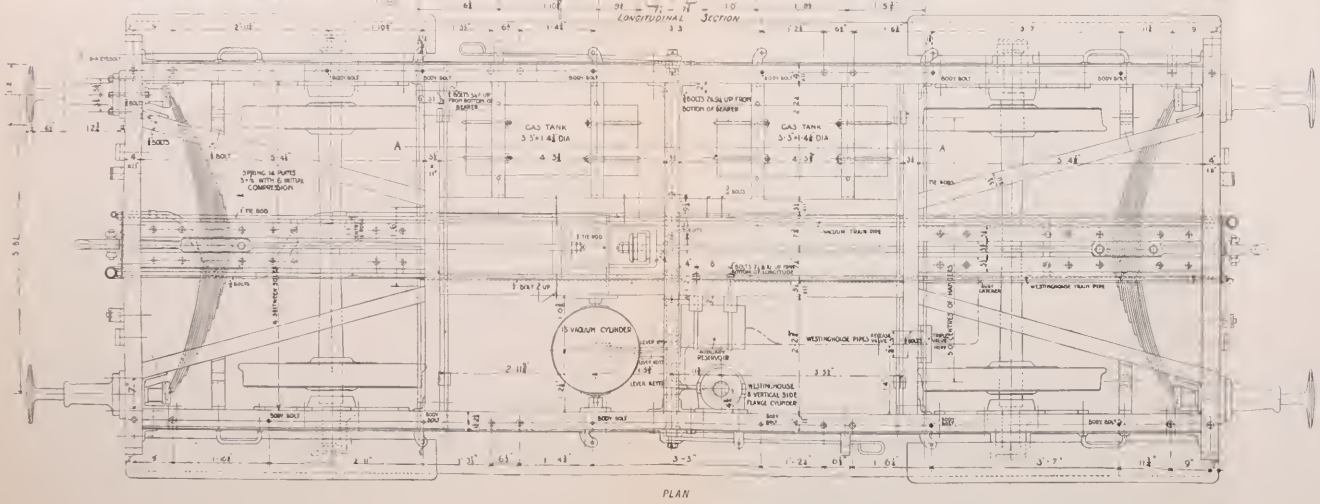












UNDERFRAME FOR 21-FT. HORSEBOX

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of the holes, mortices, and tenons are then marked by hand from the templates, which should be either of light sheet iron or well-seasoned timber, mahogany being frequently used. In general practice double tenons are adopted, and the depth of these is about one-third of the total depth of the frame, with a length varying from 1½ to 2 in., the mortises to receive them being slightly deeper. All the parts after passing through the boring, mortising, and (where required) the tenoning machines, are taken to the carriage (or underframe) builder, for each part forming the joint to be cleaned up and made true, and then thoroughly coated with white-lead paint, or jointing paste, before being driven and bolted together. All knees, &c., are similarly coated before being fixed in position, and this is particularly necessary in dealing with oak frames, as the gallic acid in the timber will in course of time rust away the iron.

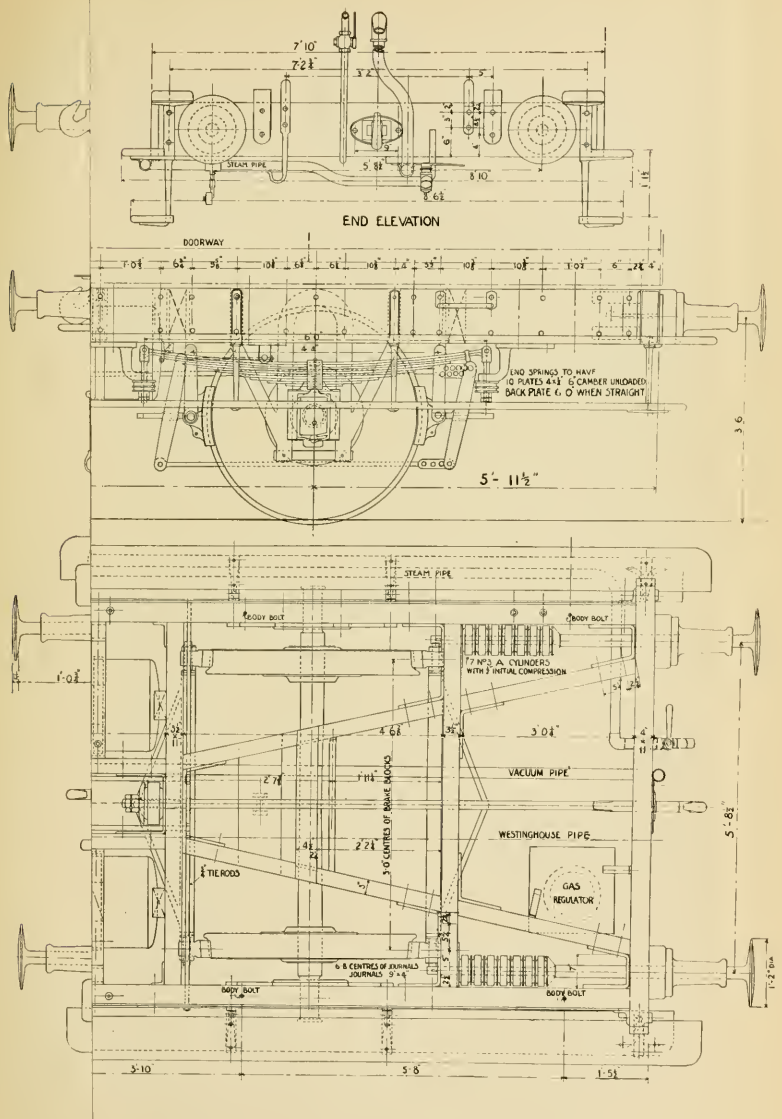
Definitions of Frame Members.—The technical names given to all the cross members (except the two end ones, which are designated headstocks) are middlebearers or crossbars; and all timbers running parallel with the axis of the frame are longitudinals, whilst those occupying an oblique position between headstock and the first bearer are diagonals. The buffing strain in the underframe illustrated in Plate II comes directly on to the two end longitudes, and is thence distributed to all the interior members, the leading headstock and diagonals taking no blow, other than the initial load on the spring, until the stroke of the buffer is exhausted, and the inside of the head strikes the casting. The drawgear is continuous, and when a train is composed of similarly fitted vehicles it has the effect that, in running, the strain of haulage is equally distributed over every frame in direct proportion to the weight of each. As regards the end vehicle, supposing the indiarubber spring in the cradle should be so weak as to be pulled home, it would bring the strain of its own dead load on the rear end longitudes, and thence be distributed throughout the whole frame.

Six-wheeled Underframe.—Plate III shows a 32-ft. six-wheeled underframe, recently designed for some specially constructed milk vans, and this frame may be taken as embodying the general principles of all six-wheeled frames. It is fitted with dual brakes, the latest arrangement of handbrake with right-hand actuating levers, and carries a through steam-heating pipe to enable the vehicle to run in any part of a steam-heated passenger train. In general, ordinary vehicles conveying passengers only are not fitted with exterior handbrakes, as they are seldom subjected to shunting singly; and the guard's vans and coaches having a guard's compartment have the handbrake actuated from inside the vehicle, so as to be always available for the guard to apply in case of emergency, or for use when shunting. The construction of this frame is similar to that of the four-wheeled one just described, but the axleguards for the centre pair of wheels are packed, and the back axlebox groove lugs either entirely dispensed with, or the groove made sufficiently wide to enable the middle wheels to have lateral movement to adapt themselves to the versed sine of any curve they may be required to travel over.

To assist this action the centre scroll irons are made much deeper than the end ones, and the spring hanger has a D shackle to allow for lateral play or movement of the wheel, axlebox, and spring. In detail this arrangement is varied by different railway companies, but the effect obtained in all cases is the same. In this underframe the draw and buffing gear are both of the indiarubber type, the former being effected by a cylinder placed behind the second bearer from each end with initial compression of 1 in. equal to 38 cwt., and the latter by means of seven small indiarubber cylinders placed in front of the first bearer at all four corners, each spring having an initial compression of $\frac{1}{2}$ in., equivalent to 19 cwt. In this case the diagonal members of the frame occupy a most important position, as it will be seen readily from the illustration that they take part of the stress, both in buffing and drawing. For this reason they are well supported by knees at the three points of jointing. Although this type of drawgear is what is technically known as " non-continuous ", it will be seen that the strains of drawing are very effectually distributed by the method adopted of placing two long $1\frac{1}{8}$-in.-diameter tie-rods to connect the two draw crossbars together; and although it may be conceded that the use of pairs of shorter rods from bearer to bearer as adopted by some railway companies is perhaps a better arrangement, owing to the shrinkage of the cross timbers, the former construction has proved very efficient when the rods are kept well tightened up to their work. In all cases great care should be taken to ensure that the frames are perfectly square and out of winding before being lined off for the fixing of the axleguards and scroll irons. Should the latter not be placed perfectly true, the running of the vehicle would be considerable affected thereby, and heating of the journals, unequal wearing of tyres, and possibly leaving the rails may be the direct result.

Short Vehicles for Suburban Trains.—Before proceeding to describe and illustrate long underframes of bogie carriages, the writer proposes to devote a short space to considering more closely the statement made in the opening paragraph of this chapter, as to four- and six-wheeled carriages still being in use for some suburban services and desirable for certain traffic. Carefully compiled statistics on this subject have shown that with such carriages the dead load per passenger is 5 cwt. 1 qr. 18 lb. on the average, whereas in long bogie vehicles this weight rises to 6 cwt. 3 qr. 21 lb., or an increase of 28 per cent per passenger, a very important item when haulage is taken into account. Again, in comparing the initial cost of bogie trains with those composed of four- and six-wheeled vehicles, taking carrying capacity into account, the former are about 20 per cent more expensive, so that it is not difficult to follow the reason for the retention of the latter stock in the suburban services of densely populated districts, such as those of the Great Eastern and North London Companies. The main objection to short carriages having limited wheel bases is the more or less uncomfortable riding, due partly to the continual jarring of the wheels on the rail joints (which jarring is considerably accentuated by any unevenness in the permanent way), and partly to the vehicle being too light to resist jumping when going

PLATE III



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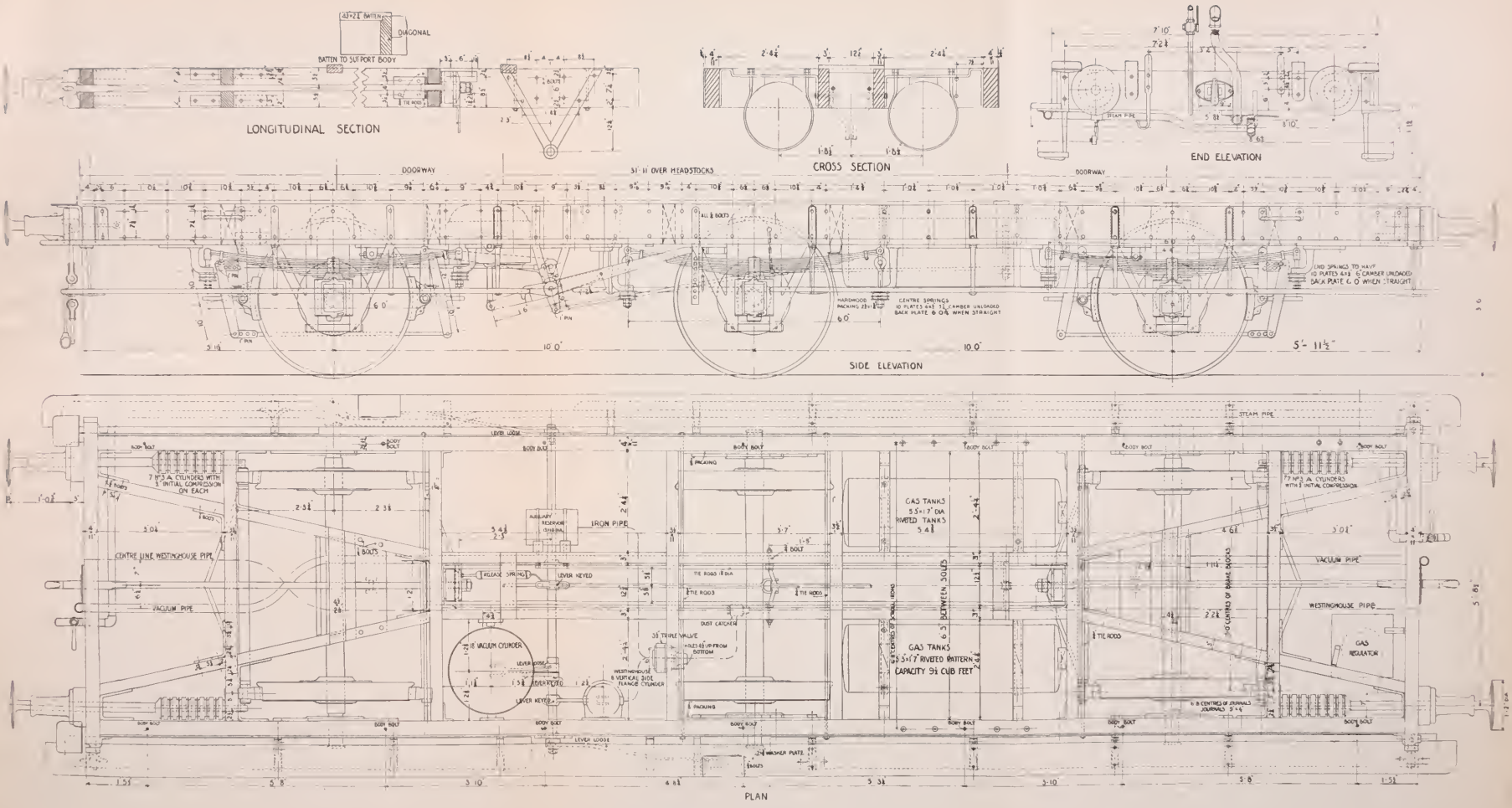

UNDERFRAME FOR SPECIAL MILK VAN

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over points and crossings, and to the rigid wheel base giving no latitude for the wheels to adapt themselves to curves, &c. In connection with this it is important to remember the fact that the increase of haulage of bogie trains per passenger is not fully commensurate with the greater dead weight,

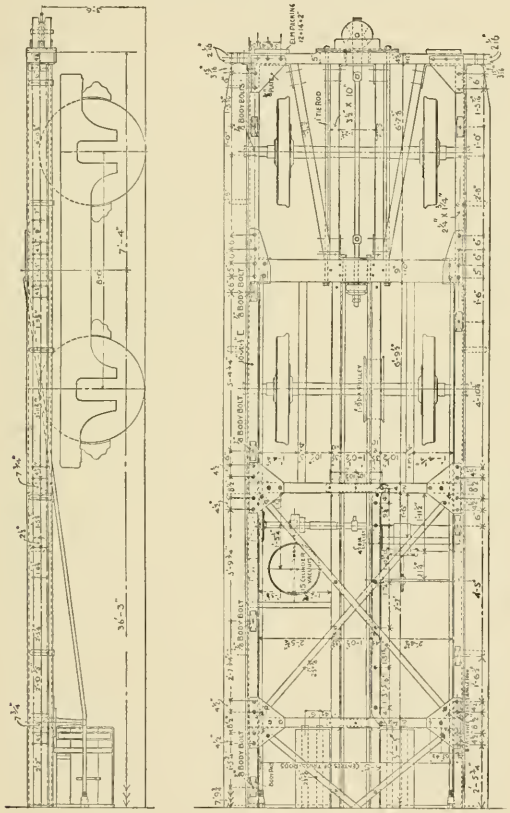


Fig. 1.—Underframe for 51-ft. Bogie Third-Brake Block Train with Channel Steel Solebars

as, owing to the flexibility of the wheel base, they travel much more smoothly around curves and over crossings. This adaptability also is a large factor in the superior riding qualities of the bogie vehicle, added to which is the increased distance between the wheels and the greater number of springs by which the body and underframe are carried, and their relative position for absorbing shocks. It may be mentioned that bogie suburban trains

have a slight advantage over four- and six-wheeled ones in the matter of platform space occupied in proportion to passengers carried, which, of course, is due to the lesser number of spaces between vehicles.

Bogie Coach Underframe.—In figs. 1 and 2 there are illustrated a bogie-carriage underframe of what is known as a composite type, both timber and steel being used for its main members. The solebars are of mild steel channels of 10-by-4-by-$\frac{1}{2}$ in. section, with $1\frac{3}{8}$-in.-diameter truss rods supporting the centre.

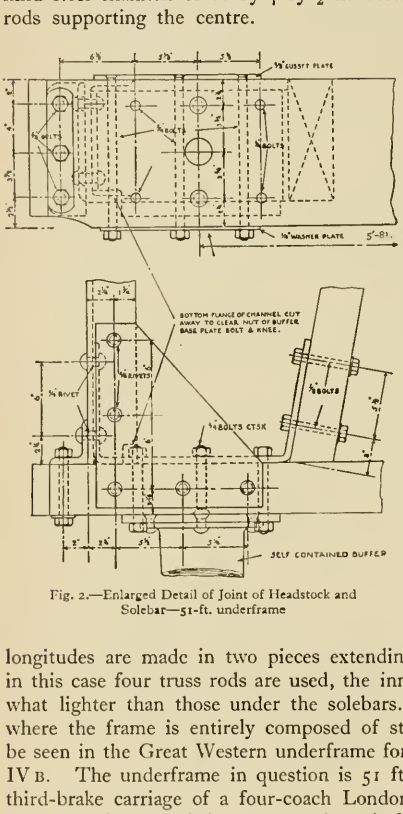
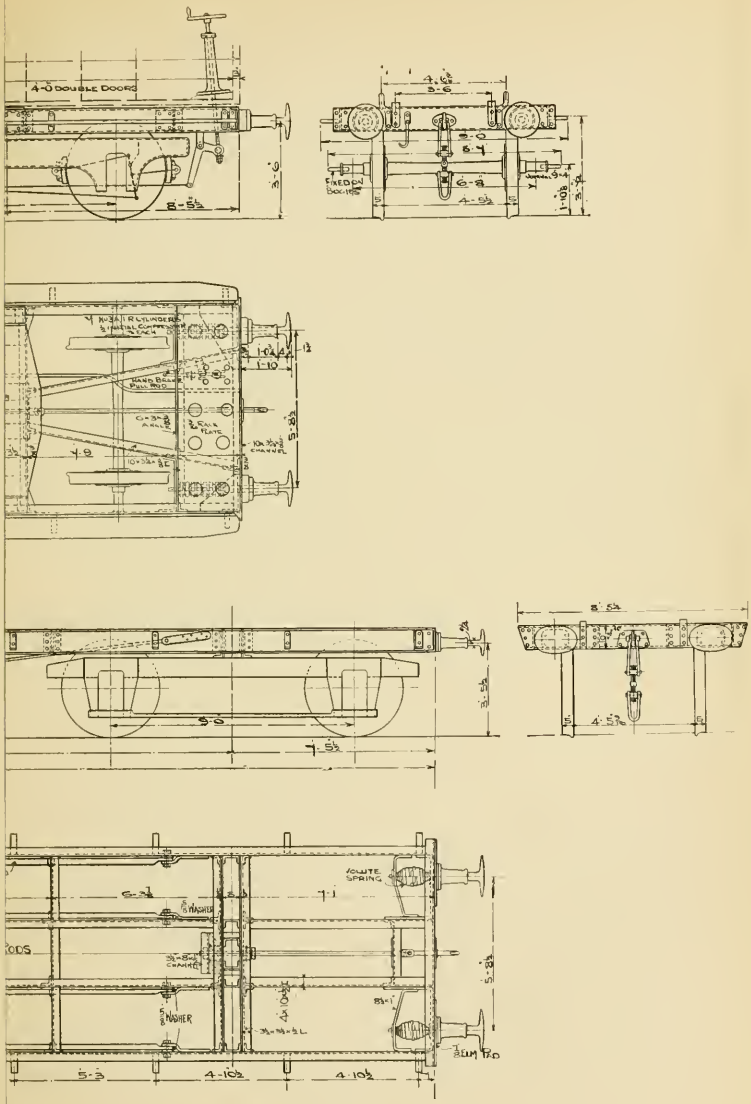


Fig. 2.—Enlarged Detail of Joint of Headstock and Solebar—51-ft. underframe

The interior members are all of well-seasoned Stettin oak, and this kind of frame has been extensively built with very good results. Its adoption for medium-length bogie vehicles is due to the difficulty in obtaining suitable oak of the length required for the solebars, and although pitch pine is available, and is occasionally used as a substitute, it is not considered sufficiently reliable to warrant its extensive use. Splicing of wooden solebars is sometimes done, but is not to be recommended. The trussing of the solebars is of the "queen post" form with rods $1\frac{3}{8}$ in. diameter, with solid plate ends securely bolted to the solebar and bolster at the point where the latter joins the former. In some cases the centre longitudes are made in two pieces extending from bolster to bolster, and in this case four truss rods are used, the inner ones generally being somewhat lighter than those under the solebars. This, however, is only done where the frame is entirely composed of steel, an example of which will be seen in the Great Western underframe for a 70-ft. coach shown in Plate IV B. The underframe in question is 51 ft. long, and belongs to a bogie third-brake carriage of a four-coach London block train, the latter being as usual close-coupled to economize platform space. Such trains run intact continually without being divided except for the purpose of repairs, &c. One end of the frame clearly shows the arrangement of close coupling adopted in this case, the distance between the headstocks being $15\frac{3}{4}$ in. as against about 42 in. between ordinary vehicles when coupled. In bogie



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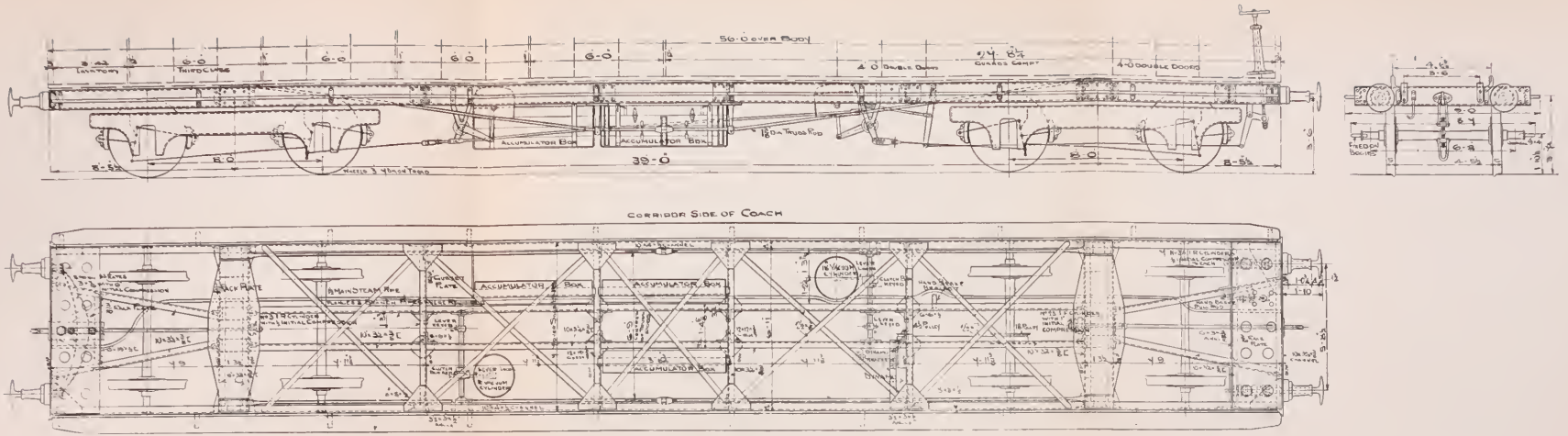
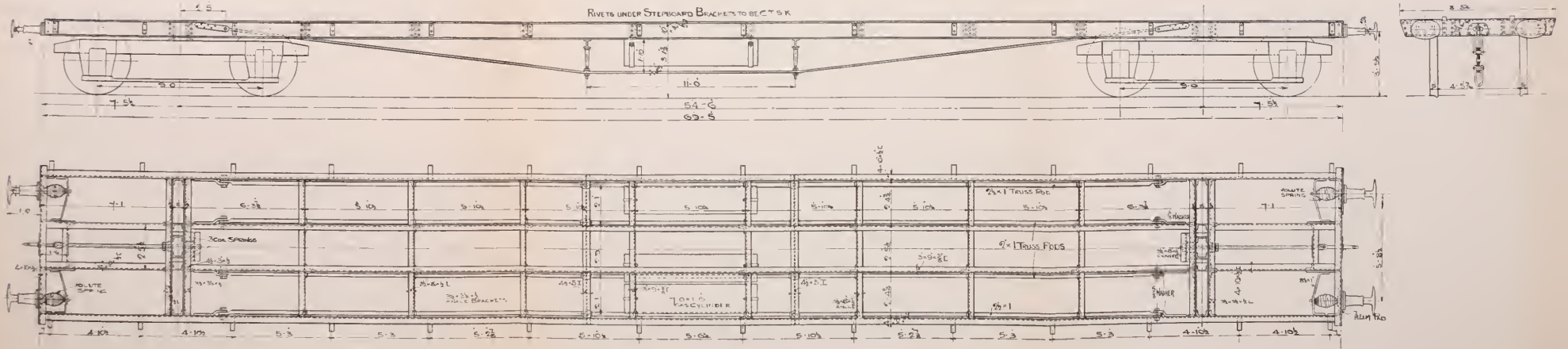


(A) LONDON AND SOUTH-WESTERN RAILWAY 56-FT. CARRIAGE UNDERFRAME



(B) GREAT WESTERN RAILWAY 70-FT. CARRIAGE UNDERFRAME

vehicles close coupled with this arrangement the distance between headstocks will vary slightly, being made greater in proportion to the length of coach, so as to have sufficient clearance between the body cornices when travelling over the sharpest curves.

Buffing of Close-coupled Vehicles.—As will be seen in fig. 1, the side buffers are entirely dispensed with, the buffing being done on to an elliptical-shaped cast-iron ball or block through which the connecting drawbar works. The drawbars proper are fitted with a large indiarubber spring behind each bolster, screwed up with a high initial load of $3\frac{3}{4}$ tons; consequently in ordinary running very little buffing action takes place, and this arrangement gives admirable results with a very low cost for maintenance. It is, however, not recommended as suitable for speeds over 40 to 50 miles

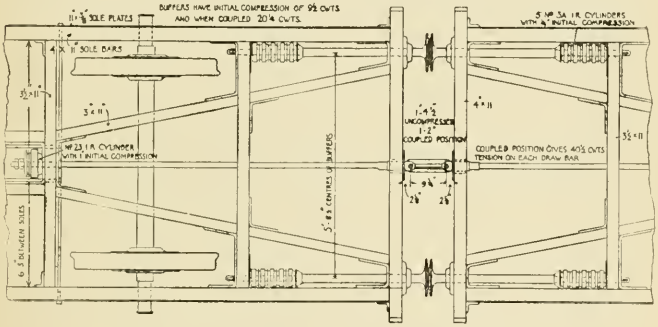


Fig. 3.— Arrangement of Close Coupling on 4- and 6-Wheel Block Trains

per hour, as beyond this the loss of the steadying action of the ordinary side buffers becomes apparent. This is, however, not the only method of close coupling in use, and the arrangement more generally used on British railways for suburban trains is illustrated in fig. 3. The initial loads on buffers and drawgear are given on the drawing.

Shrinkage, &c., in Underframes.—Adverting again to fig. 1, it will be seen that the frame is kept perfectly square by means of diagonal plates, and perhaps the principal defect in such a frame is due to the after shrinkage of the bearers; as, although well-seasoned timber may be used when building, some amount of shrinkage will undoubtedly take place after the vehicle has been in traffic for, say, two years. The means adopted for remedying this is to drive in thin pieces of iron plate where required between the knees and bearers and rebolt up, after which (writing from experience extending over many years) no further trouble need be anticipated. For the reason of shrinkage just quoted, the bolster bearers, which take the centre pin castings and side friction blocks, are sometimes built up of plate and timber in layers instead of being 10-by-9 in. solid oak, as shown on the drawing, or two steel channels may be used. The latter

make the best and strongest job, and, giving practically no deflection at the centre, save much trouble in the packing of the centre pin castings, which is frequently necessary with wood bolsters (due to deflection and shrinkage) in order to keep the weight off the side friction blocks. A detail drawing

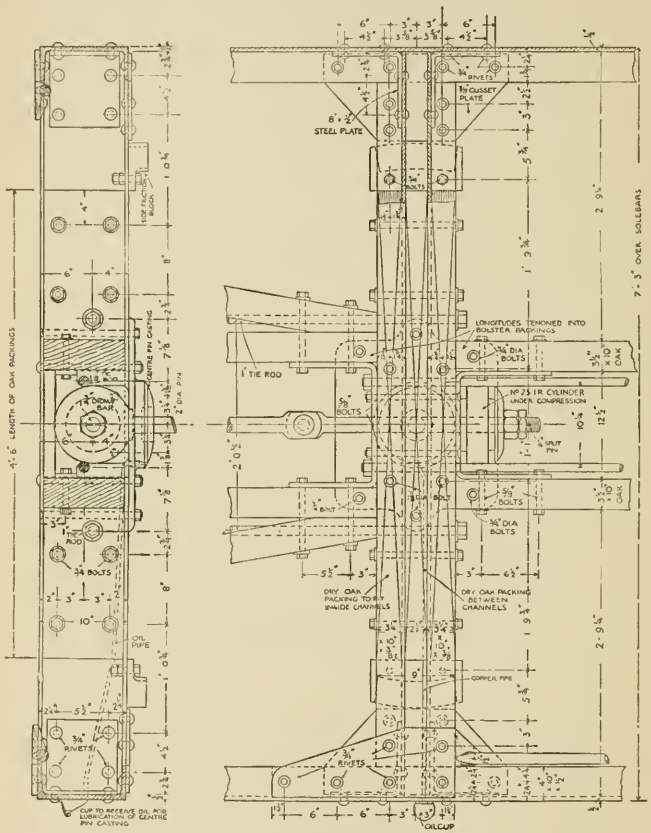


Fig. 4.—Detail of Steel Channel Bolsters for Carriage of Bogie Block Trains

showing the arrangement of a bolster built up with channels and dry oak is shown in fig. 4, and on the same illustration will be seen the method adopted to permit the centre castings being oiled from time to time in traffic.

Construction of All-steel Underframe.—In the accompanying Plate IV, A, is a 56-ft. steel underframe, the solebars of which are 10 by 4 by $\frac{1}{2}$ in. channel section, and all the interior members and headstocks are

of a similar section, 10 by $3\frac{1}{4}$ by $\frac{3}{8}$ in., with the exception of the two diagonal tie-pieces, which are made from 6 by 3 by $\frac{3}{8}$ in. angle steel, and 6 by $3\frac{1}{2}$ by $\frac{1}{2}$ in. channel steel. The material for these frames is specified to contain not less than ·1 per cent and not more than ·15 per cent of carbon, and to be guaranteed to stand a tensile strain of from 24 to 30 tons per square inch, with an elongation of not less than 18 per cent in 10 in. The straightening of the various parts is usually done in a horizontal bar-straightening machine worked by hydraulic power, after which they are cut to the required lengths by cold saw. The ends of the bars are milled, where required to fit into one another, by special machines, and, after marking out, the drilling is done on machines having multiple drills. The parts for one frame having been assembled approximately in the positions they will ultimately take, the connecting knees, gusset, rack, and lozenge plates are then bolted up. If the frame is now found to be perfectly true and square, the diagonal braces are offered up and the holes carefully marked for drilling. The riveting is usually effected by Boyer's pneumatic hammers driven from a compressed air plant, with a pressure averaging 80 lb. to the square inch; and if it be found that an additional hole or two are required, these may be put in by pneumatic drills. One end of this frame is fitted with laminated buffing and drawgear, and the other end (owing to the hand-brake spindle coming close inside the headstock, where it would foul a laminated spring) is fitted with indiarubber buffing and drawgear, the latter pulling on the bolster bearer. Very little further description is necessary, as many of the remarks made in the previous pages apply to this frame also; but it may be pointed out that, all the joints being well tied, and the ends having rack plates, these frames are exceedingly strong, and in the event of collision would offer great resistance to collapse. The weight of this underframe, complete with dynamo, accumulator boxes, steam pipes, truss rods, and other fittings (not including wheels or bogies), is $8\frac{1}{4}$ tons.

Great Western 70-ft. Underframe.—The writer is indebted to Mr. G. J. Churchward, of Swindon, for the drawing of a 69-ft.-5-in. underframe used by the Great Western Company for its longest carriages (Plate IV B). The solebars are of channel section 10 by 4 by $\frac{1}{2}$ in., and the centre longitudes of the same section 9 by 3 by $\frac{3}{8}$ in. These extend from bolster to bolster. All the intermediate tie-pieces are of angle section 8 by $3\frac{1}{2}$ by $\frac{1}{2}$ in. Four truss rods are used, all of rectangular section, the outer ones being $2\frac{1}{2}$ by 1 in. and the inner ones 2 by 1 in. The truss supports are riveted to girders 5 by 4 by $\frac{1}{2}$ in., and the necessary adjustment is made vertically. The buffing is done on to volute steel springs supported by plate knees, and each drawbar pulls on to three coil springs supported behind the bolster beams. The faces of the buffers are of oval shape, 19 by 12 in., in order to prevent any probability of buffer-locking in passing over quick curves.

CHAPTER IV

Bogies

Before proceeding to describe and illustrate the various forms of bogies in general use in this country for long carriages, it may be well to explain briefly the action of six-wheeled vehicles in passing over curves, in order that the reader may see better the reason for the adoption of the bogie vehicle and its superiority of riding, due to the trucks constantly running tangentially to any curve on the road.

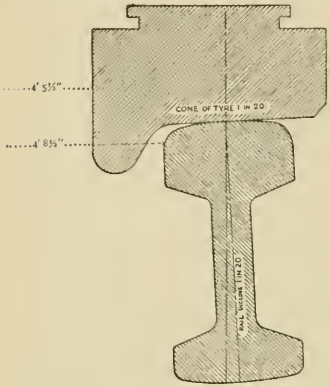


Fig. 5.—Section of Tyre and Permanent-way Rail
Tyre in the normal position on straight road

Although a theoretical ideal would be to have the wheels running loose on the axles of railway carriages similar to those of road vehicles, in order that in passing around curves the inner wheel might adapt itself to the lesser distance that it has to travel, this in railway rolling stock has been found quite impracticable, and in all cases the wheels are rigidly fixed on to the axles. Consequently on curves the inner one must have a

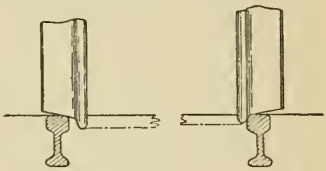


Fig. 6.—Diagram showing Relative Positions of Wheel Tyres on Rails when Vehicle is travelling over a Curve

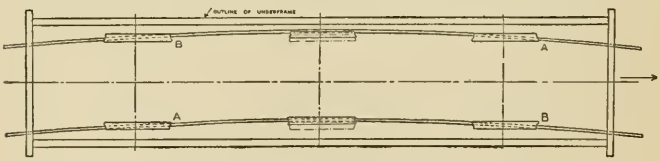


Fig. 7.—Diagram of Six-wheeled Vehicle on a Curve

circumferential slip, and to assist this the tread of the tyres is coned 1 in 20, as shown in fig. 5, which illustrates a section of the latest railway carriage tyre and permanent-way rail as recently adopted by nearly all English and Scottish railway companies. The tyre and rail are shown placed in their normal position on a straight road with the standard distance between the rails of 4 ft. 8½ in.

In the next illustration (fig. 6) the relative positions of the tyres on the rails are shown when the vehicle is travelling over a curve. It will be seen that the outer wheel is running on a greater circumference and the inner wheel on a lesser circumference, due to the coning of the tyres; but this coning is not sufficient for sharp curves, and is in fact only theoretically correct for a curve of a certain radius, and, as the constant wear of the tyres has a tendency to reduce the cone, "slipping" takes place to a considerable extent.

In fig. 7 is shown the relative position of the wheels of a six-wheeled vehicle in passing over a curve, the sketch being made out of true proportion in order more fully to illustrate the points to the reader. Assuming the vehicle to be travelling in the direction of the arrow, it is quite evident that the tendency of the wheels A is to mount the rails, and that they are only prevented from doing so by the action of the rails against the flanges, assisted by the grinding action of the check rail on the flange of wheels B. From this diagram it will be seen that in all cases the centre wheels of a six-wheeled vehicle must be practically radial to the curve, and for this reason the lateral play referred to in the description of a six-wheeled underframe (p. 99) is given to enable the wheels to retain their normal position on the rails.

The formula $V = R - \sqrt{\left\{R^2 - \left(\frac{B}{2}\right)^2\right\}}$, where R = the radius of the curve in feet, B = total wheel base in feet, and V = versed sine of the arc, will give approximately the amount of lateral play necessary to be allowed; but in practice this is seldom adhered to, as the clearance allowed on the ends of the bearings, together with the additional allowance made in the distance between the rails on curves, is generally sufficient to permit of from 10 to 20 per cent reduction on the theoretical figure. The position of the bogies of a 56-ft. carriage when on a 5-chain curve is illustrated in fig. 8, showing how the wheels keep tangential to the curve. Owing to the fact that the trucks are, for bearing purposes, in contact with the underframe only at the centre pivot plates, they are quite free to radiate and adapt themselves to any curve of the road.

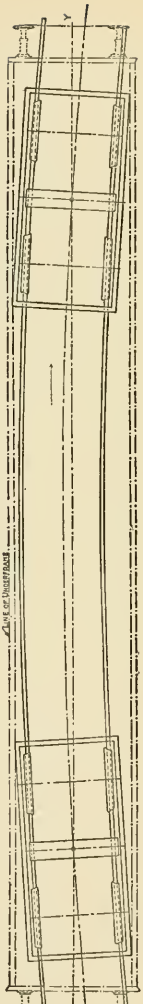


Fig. 8.—Diagram showing 8-ft. Wheel-base Bogies 30 ft. centres on a 5-chain curve

Here may be pointed out the necessity of making the buffer heads sufficiently large to prevent them locking on curves, and also for adequate side clearance to be given to the drawbars, as on reference

to the diagram (fig. 8) it will be seen that the centre line of the underframe X Y differs considerably from the centre line of the rails at the line of contact of the buffers.

In this illustration the centres of the bogie wheels are shown 8 ft. apart,

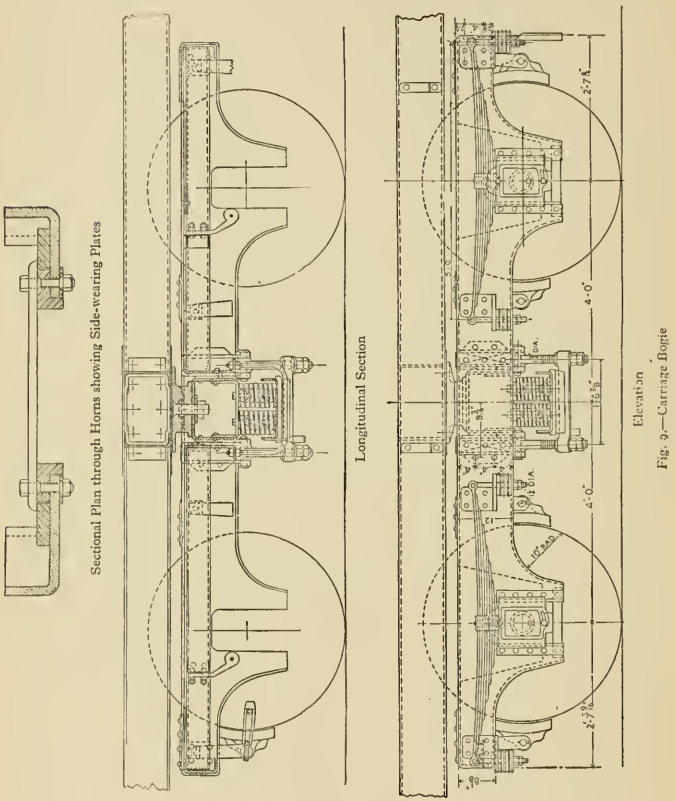


Fig. 9.—Carriage Bogie

and this figure may be taken to represent general practice in this country; and although theoretically the correct wheel base of bogies is frequently quoted as one and half times the rail gauge, i.e. $\left(4 \text{ ft. } 8\frac{1}{2} \text{ in.} \times \frac{3}{2}\right)$ equal to $7\frac{7}{16}$ ft., this dimension is seldom adhered to. Four-wheeled carriage bogies with wheel bases varying from 6 ft. 6 in. to 10 ft. are in use on various railways, and for six-wheeled trucks the wheel base is generally 12 ft. Whilst

flange friction is lessened by the bogie wheels being close together, due consideration of the fact that the truck is guided in its travelling by the hind wheel makes it evident that the nearer the axles are together the greater the tendency to swerve the bogie in the opposite direction to the rails by its

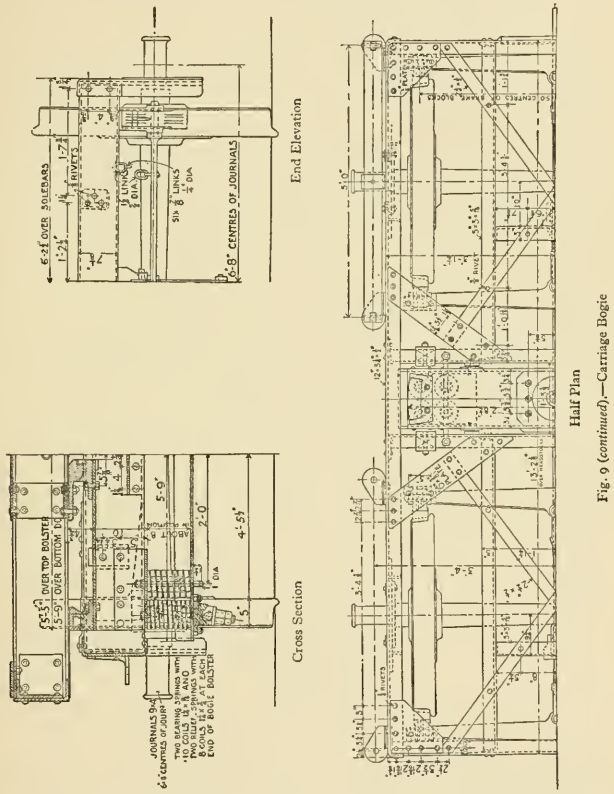


Fig. 9 (*continued*).—Carriage Bogie

turning on the centre pin; hence the theoretical ideal as to the wheel base not being less than the figure just referred to.

General Features of Pressed-steel Bogies.—In fig. 9 on pp. 108–9 is illustrated the most general form of bogie in use in this country and abroad, and although the parts and details vary on different railways the principle is practically the same. In the illustration the framing shown is of pressed steel; but bogies are more generally constructed of ordinary

angle or channel sections, the only advantage of the pressed-steel parts being that they are somewhat stronger in proportion to weight than ordinary rolled sections. Wood and plate frames (sandwiched) were extensively used some years ago, and many are still running, but are now seldom built, as the all-

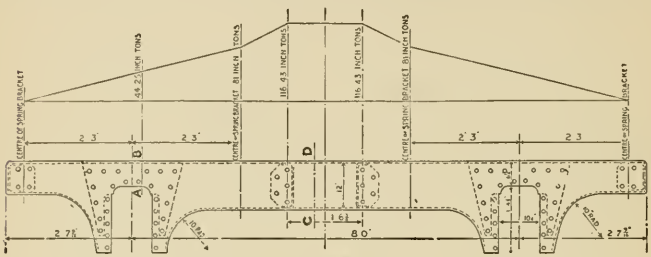


Diagram of Bending Moment of Solebar

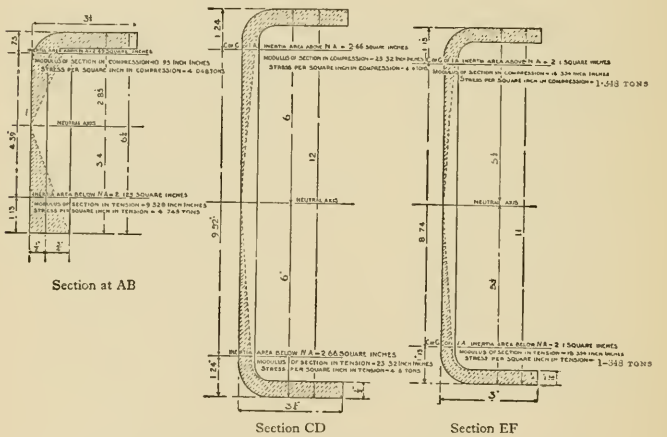


Fig. 10.—Stress Diagrams. Bogie under a load of 12 tons

Pressed parts enclosed by full lines; inertia areas by dotted lines and sectioned. Stress on material = $\frac{\text{Bending moment in inch tons}}{\text{Modulus of section in inch inches}}$. These diagrams do not take into account stress due to brake arrangement, which increases the stress on solebars.

steel frame is far superior in rigidity, the latter being a most important point to consider.

The English technical names of the frame members follow closely the terms applied to a four-wheeled underframe, i.e. soles, headstocks, bearers, and end longitudes, the only difference being that in each case the word " bogie " is prefixed, so that the part referred to may be readily distinguished

in the workshops. The truck illustrated in fig. 9 is suitable for a vehicle up to about 30 tons total weight, and, as will be seen, the load is carried on dished plates at the centre of a loose beam technically called a top bolster, under the extreme ends of which are placed springs resting on a tie-beam (known as the bottom bolster), which is suspended from the crossbars of the bogie frame by swinging hangers passing through the ends of a connecting or rocking bar. The latter has a " vee " or knife-edge-shaped section at the centre, which works in a corresponding groove of a casting (technically known

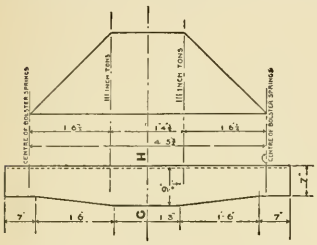


Diagram of Bending Moment of Top Bolster

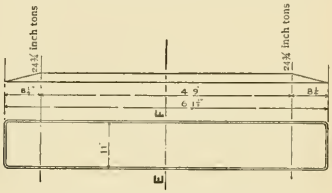
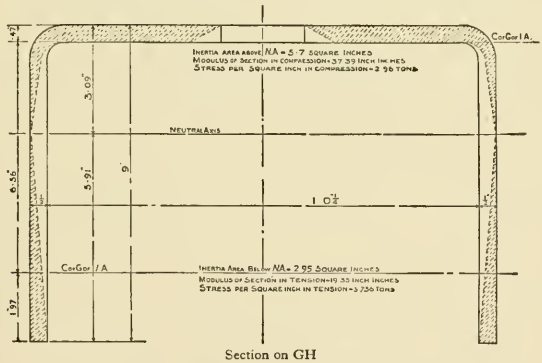


Diagram of Bending Moment of Crossbar


Inertia Area above NA = 5 7 Square Inches
Modulus of Section in Compression = 37 39 Inch Inches
Stress per Square Inch in Compression = 2 56 Tons
Neutral Axis
Inertia Area Below NA = 2 95 Square Inches
Modulus of Section in Tension = 19 33 Inch Inches
Stress per Square Inch in Tension = 3 726 Tons
3 09"
5 91"
9"
1 0½
6 36"
1 97"

Section on GH

Fig. 11.—Stress Diagrams. (See Fig. 10.)

as a saddle) attached to the bottom bolster in order to give freedom for the swinging action of the bolsters on curves. The weight having been transmitted to the crossbars, these in turn transmit it to the solebars, to which are riveted brackets carrying it on to the laminated side springs and thence to the axleboxes and journals. Auxiliary bearing springs either of indiarubber or steel are generally placed under the side-spring brackets, as shown in the drawing. It will be seen that the dished plates referred to above actually consist of two castings, which at the points of contact are made concave and convex respectively, the object of this shape being to relieve the centre pin of a considerable part of the shearing stress. On some lines this form

of centre-pin casting has been superseded by a pair, the parts fitting almost vertically one into the other, and the top one bearing on a flat surface, parallel with the top of the bolster, thereby practically eliminating all motion other than radial. It may be mentioned that on all bogie carriages (particularly heavy ones) these castings work better together if fitted with oiling tubes leading from a convenient position on the outside of the underframe solebars, so that they may be periodically oiled without lifting the vehicle (see fig. 4).

A diagram of bending moments of the solebars, crossbars, and top bolster of this bogie is shown in figs. 10 and 11, which will the more readily assist the reader to see quickly the distribution of the weights and stress on these parts. The modulus figures with stress per square inch on section are also given for the frame members on the same illustration. It will be noticed that the weakest parts of the solebar are immediately above the crown of the axleboxes, where the bar is cut out to give sufficient clearance, so that the vehicle may come down on its springs when loaded, but without touching the axleboxes, which would, of course, produce a series of bumps in the riding. This weakness is made good by riveting on the inside a $\frac{3}{4}$-in. steel lining plate, which can be seen in fig. 10.

Action of Bolsters on Curves, &c.—Having described the general construction of what may be called the standard carriage bogie, we may briefly explain the action of the swinging bolster when the vehicle is passing over curves. It will be noticed that the bolster suspension hangers are inclined outwards (general practice gives 1 in 6 to 1 in 9), the object of this inclination being to resist lateral movement with resulting " sloppy " riding at high speeds, and also to assist the vehicle to maintain its normal position when travelling over curves.

The friction castings at the ends of the top bolster, which engage with similar castings on the underframe, are merely guides or distance pieces to prevent side rocking, so that to give free action of the bogie these friction blocks should be about $\frac{1}{16}$ in. apart when the coach is standing level, thus assuring that the weight is being carried on the centre of bolster beams only.

The wear on the inside of the horns due to the friction from the axleboxes is fairly considerable, and, to enable this to be repaired cheaply and quickly from time to time, it will be noticed that the pieces in actual contact with the box are separate from the solebar and only riveted thereto. An enlarged section through the horns clearly shows this detail (fig. 9), and the section of steel required for renewing is rolled, and purchased in bars to suit, and then cut into the lengths required by cold saws.

In fig. 9 the bolster springs are of the helical pattern, eight for each bogie, the outer four having an internal diameter of 3 in., with a rectangular section $1\frac{1}{4}$ in. by $\frac{5}{16}$ in. and 10 in. high unloaded. The inner springs have an internal diameter of 3 in., with a rectangular section of $1\frac{1}{4}$ in. by $\frac{3}{4}$ in. and $8\frac{1}{2}$ in. high. When the springs are thus arranged, the outer four to each bolster are sometimes termed the " bearing " springs and the inner four the " relief " springs.

Some companies use only two springs at each end of the bolster. They are generally placed at right angles to the centre line as drawn longitudinally with the coach.

Many different sections of helical and volute springs are in use on bogies in Britain, but perhaps the best known is the differential section of helical springs patented by the late Mr. I. A. Timmis, of London. This section has been more or less used by many railway companies, it being claimed that this particular design absorbs shocks and produces better riding. A section of one of these steel springs is shown in fig. 12. Some railway rolling-stock engineers consider the laminated bolster springs to give the best results in easier riding, and consequently they use either double, triple, or quadruple elliptical springs, according to the weight of coach. These springs are fully illustrated on the next bogie described (fig. 13).

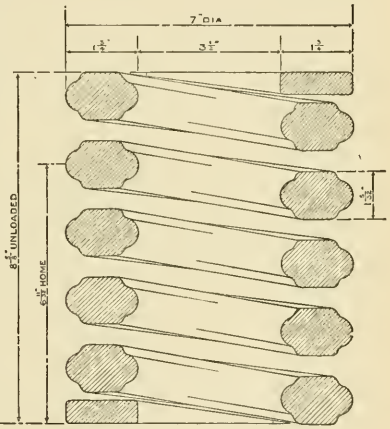


Fig. 12.—Timmis's Bogie Bolster Bearing Springs

The Equalizing-bar Bogie. — The equalizing-bar or compensating-beam bogie shown in the next illustration (fig. 13) is a general form and type of truck adopted in America, and is fairly common on British railways.

The Great Western Company a few years ago constructed a large number of this type, and the writer is indebted to Mr. G. J. Churchward, locomotive and carriage engineer of that company, for the illustration given. The principle of the swinging bolster and suspension hangers described in the preceding paragraphs applies to this one also, but the chief difference is that the weight, when taken on the solebars, is transmitted through coil springs to a heavy section bar, technically known as an equalizing or compensating beam, which generally rests at each end on semicircular seatings cast on top of the axleboxes. In the Great Western bogie illustrated the ends of the bars are bolted to lugs on the boxes. It is of great importance in designing this class of bogie that the equalizing beams be made sufficiently strong not to bend or spring, as, if this takes place, the axleboxes become tilted inwards, considerably increasing the friction on the horns, and producing bad riding. Again, these bars are liable to considerable vibration and shocks, and in designing it is advisable that the safe working load put upon them should not exceed 3 tons per square inch of sectional area. It will be noticed that each compensating beam in this case is made in two parts, each being 7 in. by 1 in. section.

This bogie gives very good results in riding, and possesses the advantage that any movement at the axleboxes caused by the wheels passing over

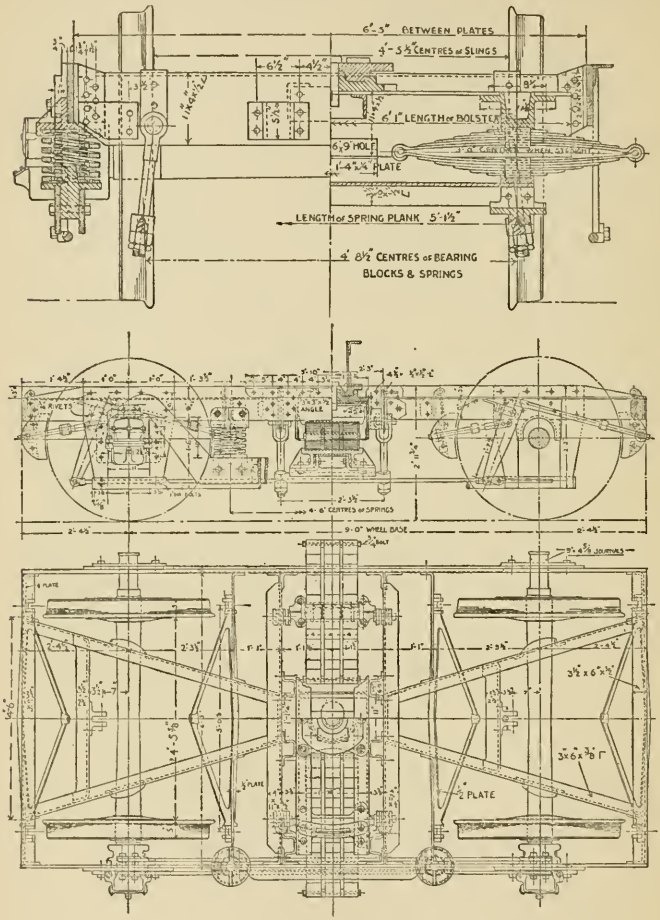


Fig. 13.—9-ft. Equalizing-bar Bogie (Great Western Railway)

crossings, &c., is somewhat minimized before reaching the passenger, due to the position occupied on the beam by the bearing-coil springs. The bolster springs in this bogie are of the laminated type, being triple elliptical,

each of the six springs being composed of six plates 4 in. by $\frac{3}{8}$ in. The strength will, of course, be the same as if three springs had been used, but the deflection in inches per ton of load will be double, owing to the position of the springs one over the other.

In both the bogies described the actual pulling force exerted on the truck is transmitted from the centre pin and castings of the top bolster on to the cross bearers by wearing plates at the ends, and herein probably lies the greatest drawback to obtaining ideal riding by the bogie arrangement.

At first sight it may be thought that a fair space (say $\frac{1}{4}$ in.) could be left between the bolster and bearers on each side, to minimize vertical friction when once the vehicle is moving; but this is impracticable, and would lead to the brake blocks dragging on the tyres, due to part of the brake work being attached to the underframe and the other to the bogie, connected only by a rod or rods. Reference to the drawings showing the brake arrangement will make this point clear. It is therefore only possible to give just sufficient clearance to permit the bolster to move laterally as the vehicle passes over curves.

It is quite obvious that perfect freedom of action, vertically and laterally, of the top bolster cannot take place whilst considerable friction is going on longitudinally, i.e. parallel with the centre line of pull on the coach, and although oil and grease may minimize the trouble it cannot entirely overcome it. Several inventions dealing with this subject have been patented, all aiming to produce smoother and easier riding, but, so far as the writer is aware, none has met with any general adoption in this country.

The two types of four-wheeled bogies already illustrated represent by far the greater proportion of those running on the railways in Britain; but for very heavy and long vehicles many six-wheeled bogies are in use, in order that the weight may be distributed over more journals and to maintain a distance between the inner wheels not exceeding the length of the permanent-way standard locking bar.

London and North-Western Railway Six-wheeled Bogie.—An illustration of a six-wheeled bogie is given in fig. 14, which is the design used on the London and North-Western Railway.[1] It will be seen that the principle of the six-wheeled truck is really a double application of the swinging bolster of a four-wheeled bogie, the weight being carried on to the two parallel bolsters by a connecting beam to which the bottom centre pin casting is attached.

The wheel base of this truck is 11 ft. 6 in., and the soles are constructed of mild-steel angles 12 in. by $4\frac{1}{2}$ in. by $\frac{3}{4}$ in., and the crossbars of channels 8 in. by $3\frac{1}{4}$ in. by $\frac{5}{8}$ in. These bogies are used under the London and North-Western Company's largest and heaviest carriages.

It might be conjectured that the riding of a six-wheeled bogie carriage should be markedly more smooth than one on four-wheeled bogies, as the former has frequently double the number of bolster springs and 50 per cent

[1] The writer is indebted to Mr. C. A. Park, former carriage superintendent of the London and North-Western Railway, for the drawing from which this figure was prepared.

more side springs to help in absorbing the shocks, but in actual practice this difference is not very apparent. The reason for this may be seen when it is considered that the greater the number of wheels the more will be the shocks and noise from revolving and in passing over the points and crossings, and there is also the greater amount of flange friction on the rails.

The workshop practice of preparing the materials for the construction of bogies, the framework of which is composed of angles or channels, follows very closely that described for the construction of steel underframes in the chapter on underframes, and therefore need not be repeated. When the members of the frame are, however, all made from pressed-steel plates, angle-iron joint knees can be dispensed with, the end flanges of the plates themselves being riveted to the adjoining member. Great care is taken that the bogie frames show up perfectly true and square when finished, as the riding of the vehicles and freedom from overheated journals largely depend upon this precaution.

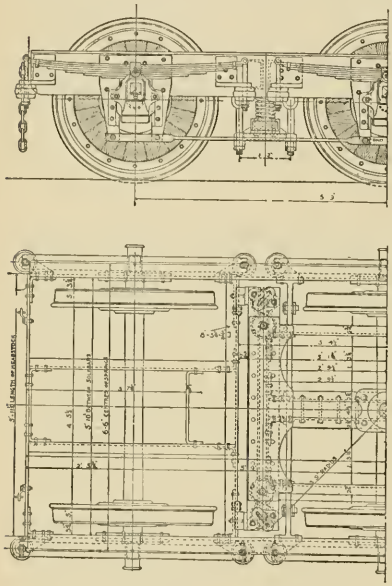


Fig. 14.—Six-wheel Bogie with 11 ft. 6 in. Wheel Base (London and North-Western Railway)

Wide-bolster Bogie.—It will be of interest to illustrate a bogie specially designed at Eastleigh works a few years ago to give steadier riding in dining and sleeping saloons, and which has given such satisfaction in use that the London and South-Western Railway Company have adopted it on all their latest corridor coaches. This bogie is illustrated in fig. 15, and it will be seen that the bolster is considerably longer than usual, enabling the bolster springs and side-friction blocks to be carried about 2 ft. 2 in. farther apart than with a standard truck. This is effected by having inner and outer soles, the former being carried from headstock to bearer only and used to secure the axleguards and to take part of the weight from the laminated side springs. The sketch clearly shows the arrangement.

Diamond-frame Bogie.—The diamond-frame bogie illustrated in fig. 16 is most extensively used for heavy bogie wagons in this country, and is the common type in American practice.

The arrangement of the truck is very strong and simple, and on reference to the drawing it will be seen that although there are no side springs, the springs under the bolsters carry as usual the weight of load, underframe, and body.

The sides are composed of three principal members, viz. the top arch bar, which is in compression, and the inverted arch bar and pedestal tie bar, which are in tension. They are connected at the ends by $1\frac{1}{8}$-in. bolts passing through the axleboxes, and near the centre by $1\frac{1}{2}$-in. bolts passing through strong cast-steel columns. The bolster is of similar arrangement to those already described, with the exception that there is no swinging action,

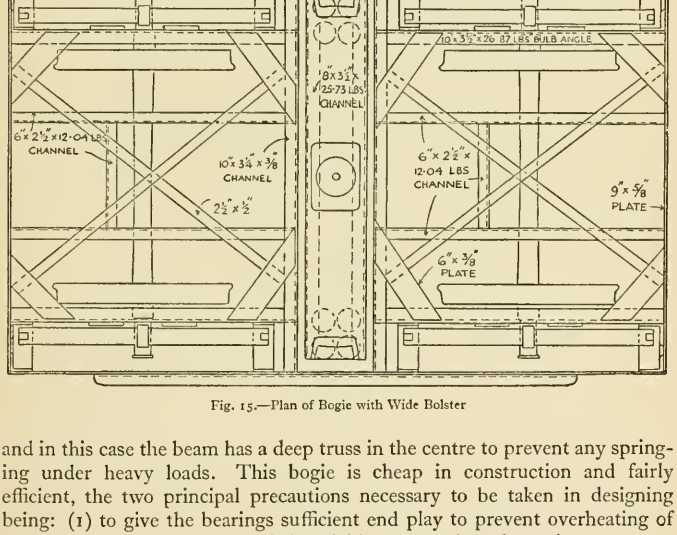
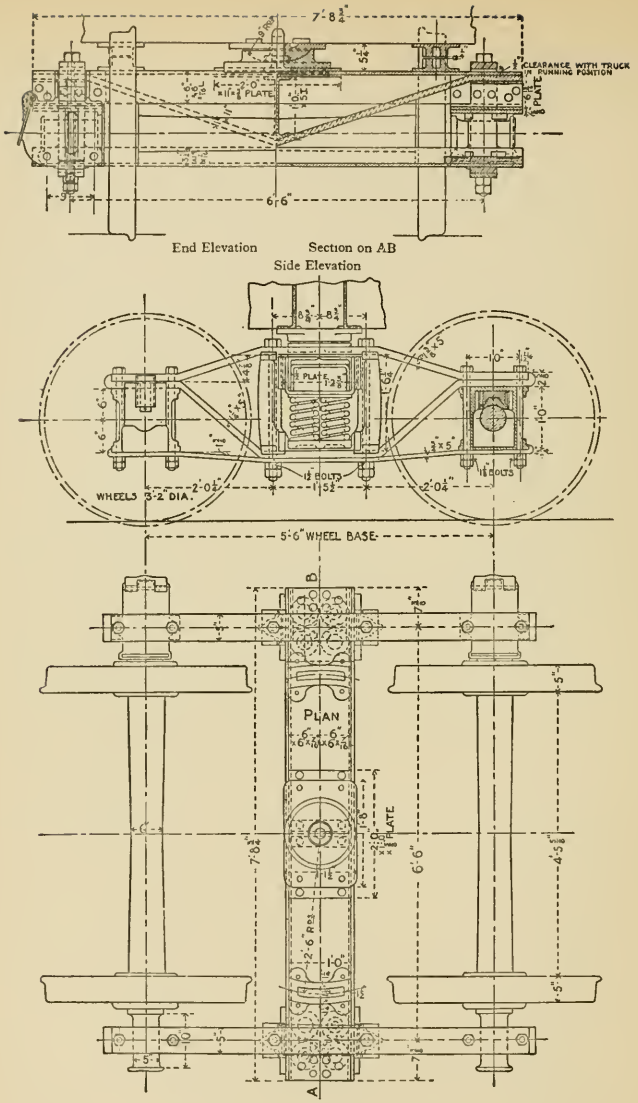

10" x 7/8" PLATE
3" x 2½" x 5/8" ANGLE
10 x 3½ x 26 87 LBS BULB ANGLE
8" x 3½" x 25·73 LBS CHANNEL
6" x 2½" x 12·04 LBS CHANNEL
10" x 3¼" x 3/8" CHANNEL
2½" x ½"
6" x 2½" x 12·04 LBS CHANNEL
9" x 5/8" PLATE
6" x 3/8" PLATE

Fig. 15.—Plan of Bogie with Wide Bolster

and in this case the beam has a deep truss in the centre to prevent any springing under heavy loads. This bogie is cheap in construction and fairly efficient, the two principal precautions necessary to be taken in designing being: (1) to give the bearings sufficient end play to prevent overheating of the journals, as the axleboxes, being rigid, cannot adapt themselves to movement; and (2) the centre column or pedestal castings should be very strong and supplied with lugs of heavy section, as they are liable to severe strains from lateral thrusts of the wheels on to the journal collars and thence to the boxes; this being due, in a measure, to there being no transverse end ties to the arch bars equivalent to the ordinary headstock.

Variation in details and springs may be observed in different builds of these trucks, but the underlying principles are the same.

Space does not permit of giving full descriptions of all kinds of bogies, and the foregoing includes only those met with generally in modern railway-carriage and wagon construction.



Plan

Fig. 16.—Diamond-frame Wagon Bogie

CHAPTER V

Wheels and Axleboxes

As the wheels and axleboxes form probably the most important details of a carriage or wagon, and a subject upon which a considerable volume alone might be written, the writer can only endeavour, in a short article, to give the reader a general idea of modern practice.

Illustrated in fig. 17 is what is technically known as a standard Mansell wood wheel. The title "Mansell" is derived from the name of the patentee, Mr. Robert Mansell, late superintendent of the South-Eastern Railway, who invented this particular arrangement of wheel many years ago. Appended is a complete specification of this wheel, and as it is now becoming a general practice to standardize such important details, this specification may be taken as embodying, with slight variation, the requirements for carriage wheels for the majority of British railways.

Mansell Wheel Specification.—The wheels and axles are to be made exactly to the form and dimensions shown in fig. 17, and the tyres and axles shall be manufactured from acid open-hearth or acid Bessemer steel, by an approved maker. The body or disc of the wheel to be of the best dry and well-seasoned Moulmein or Rangoon teak, free from heart or sap, and the grain in all cases to run lengthwise of the segments. The boss of the wheel to be of good wrought iron, and accurately turned to the dimensions shown on the drawing. The washer plate to be of good wrought iron and turned to fit the boss.

The retaining rings to be made from the best faggoted scrap iron, and to be accurately turned to gauge and template. Great care must be taken that the lips on the rings and the grooves in the tyre fit each other accurately, and that the retaining rings are exact duplicates of each other. The tyres are to be brought to a black heat, and to be shrunk on the disc of the wheel with $\frac{3}{32}$-in. contraction.

The tyres are to be 3 ft. 7 in. diameter on tread, 5 in. wide, and $2\frac{1}{2}$ in. thick when finished. They are to be accurately bored out and turned all over. The tyres to be tested shall be placed in a running position with the tread resting on a block of metal of not less than 5 tons weight, supported on a rigid concrete or other solid foundation, and must withstand, without fracture, blows from a falling weight of 1 ton. The weight must be allowed to fall freely on to the tread from heights of 10 ft., 15 ft., 20 ft., and upwards, until the deflection of the tyre corresponds to that given in the following formula in which d is the internal diameter of the tyre as rolled, in inches, and t is the thickness of the centre of the tread in inches: deflection $= \frac{d^2}{45t^2}$. Each tyre to be stamped whilst hot with the charge number, and to be capable of bearing a tensile strain of from 42 to 48 tons

per square inch of area, with an elongation of from 18 to 15 per cent in 2 in.[1]

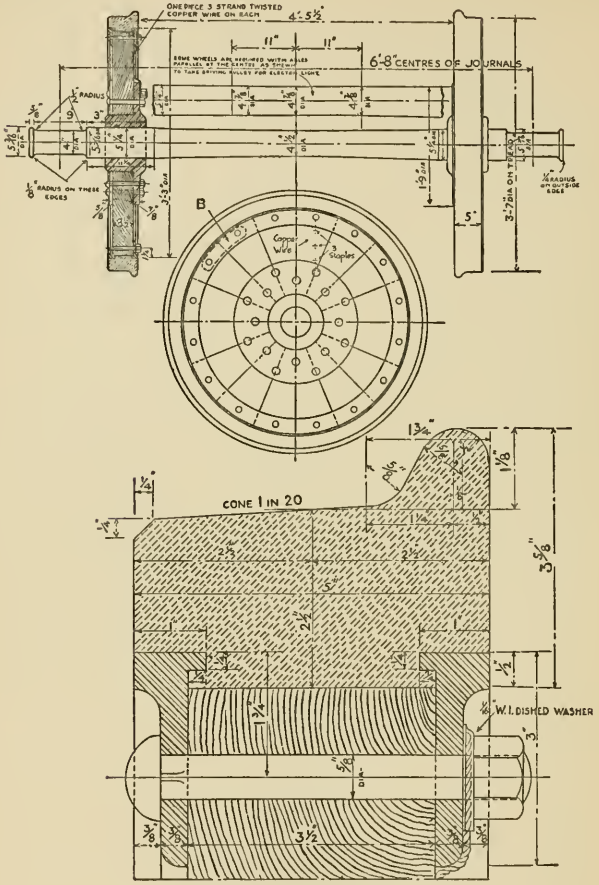


Fig. 17.—Standard Mansell Wood Wheel

[1] Until recently tyres were generally specified to have a tensile strength of from 35 to 40 tons per square inch, with a minimum elongation of from 25 to 20 per cent in 2 in. Some engineers favour tyres with a tensile strength of from 63 to 69 tons per square inch, with a minimum elongation of from 10 to 8 per cent in 2 in., and in this case the deflection in the drop test is $\frac{d^2}{60t^2}$.

The axles when finished to be exactly to the form and dimensions shown on drawing, and they shall be thoroughly annealed throughout before being turned. Each axle must be guaranteed to stand, without fracture, five blows from a weight of 2240 lb. falling from a height of 20 ft. upon the axle, which shall be placed upon bearings 3 ft. 6 in. apart, and shall be turned after each blow. The tensile strength of the axles is not to be less than 35 tons, or greater than 40 tons per square inch, with an elongation of not less than 25 per cent with 35 tons and 20 per cent with 40 tons, the sum of the intermediate breaking strengths and corresponding elongations being not less than 60. The yield point must be not less than 50 per cent of the ultimate tensile strength.

The wheels are to be forced on the axles by hydraulic pressure[1] of not less than 60 tons, and the pressure figures for " halfway " and " fully on " to be recorded by being stamped on each axle behind the boss.

Each pair of finished wheels and axles to be properly balanced in a machine designed for this purpose, and they must be driven at a speed equal to 60 miles per hour and show up perfectly true.

The wheels to be properly bonded with copper wire where shown on the drawing for track circuit signalling, so that the resistance from tyre to tyre shall not exceed ·01 ohm. The wheels may also be spot welded in three or more places between the Mansell ring and tyre.

The railway company's initials, with date and maker's name, to be legibly stamped on the tyres, axles, boss, and washer.

The woodwork to have four coats of the best varnish, and the boss and rings to be painted black and varnished. The axles and outer edges of the tyres to be painted white.

The contractor shall provide, at his own expense, one additional tyre and one additional axle out of every fifty, to be selected from the bulk by the railway company's carriage superintendent, or any person he may appoint to inspect and pass the work, and to be tested in his presence by the contractor in the manner hereinbefore described. From each axle and tyre submitted to the falling-weight tests specified, tensile test pieces (one for each) are to be prepared, and these must be broken in the presence of the person passing the work, before the bulk is accepted from the contractor.

. . . . . .

A description of the manufacture of carriage wood wheels and axles and the machinery used therein is beyond the scope of this article, but it may be mentioned that a great number of men are kept constantly employed in this branch of railway work, and the almost entire absence of any train accident arising from a defect in wheels speaks very highly for the great care and attention bestowed upon their manufacture. All wheels should be periodically tested with a back pressure of 50 tons to see that they retain their security of seating on the axle.

[1] Automatic machines for recording these pressures are now in general use, the axle being coated at the wheel seat with a mixture of white lead and boiled oil before the wheel is pressed on. Some companies use tallow only for this purpose, while others prefer rape oil.

Security of Tyres on Wood Centres.—The merit of a carriage wheel with a wood centre lies principally in the minimizing of noise, as a wheel made entirely of iron and steel gives out a somewhat metallic ring in travelling over the steel rails. It will be seen in the illustration (fig. 17) that the tyres are so fastened by lip or retaining rings, that even should a tyre break, no portion can possibly fly off, and practical experience has shown that tyres may be worn down to 1 in. in thickness with perfect safety before renewing.

Should a tire become in the least degree slack on the centre (and this may arise from getting warm owing to the constant application of the brake blocks, particularly on a short piece of road with many inclines) considerable liability exists of the boss and retaining-ring bolts wearing or cutting into the teak segments. Instances of this have arisen, and the writer saw on one occasion a wheel which, when taken to pieces, disclosed the bolt holes to be so considerably elongated that the teak segments were practically cut through.

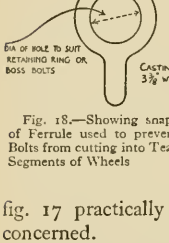


Fig. 18.—Showing shape of Ferrule used to prevent Bolts from cutting into Teak Segments of Wheels

To prevent this defect arising, some companies put a ferrule of malleable cast iron (or cast steel) of the shape shown in fig. 18 on some of the boss and retaining-ring bolts, which materially increases the surface of resistance, the ferrules themselves being driven tightly into the holes made in the teak to receive them.

Wheel Dimensions.—Until quite recently the flange and profile of carriage tyres differed on almost every company, but the rolling-stock and permanent-way engineers of the English and Scottish lines have now agreed upon a standard, and the profile shown in fig. 17 practically represents the flange section as acquiesced in by all concerned.

The diameter on tread of carriage wheels varies on different lines from 3 ft. 5 in. to 3 ft. 7½ in., but the dimension given in our illustration, of 3 ft. 7 in., is a standard with many companies. Again, the centres of journals vary from 6 ft. 5 in. to 6 ft. 8 in., and also the size of journals for ordinary stock from 8 in. by 3½ in. to 9 in. by 4 in. The latter size for carriage journals is now being very advantageously adopted wherever possible, and it is quite obvious that with the increasing weight of coaching stock, and acceleration of speeds, the larger the diameter of wheel and journal (within practical limits) the less the friction and weight per square inch on the bearing area. The Great Western Railway Company have adopted a 9-in.-by-$4\frac{5}{8}$-in. journal for their wheels under 70-ft. vehicles carried on two four-wheeled bogies. British practice, so far as friction is concerned, is that the maximum load on the nominal area of a journal should not exceed 300 lb. per square inch, i.e. the greatest load on a 9-in.-by-4-in. journal would be 300 × 36 lb. or approximately 4·8 tons. This point is referred to again when dealing with axleboxes and bearings.

In the specification given the tyres are required to be shrunk on the teak centres, but some companies prefer forcing the wood centres into position

by hydraulic power of not less than 200 tons, and in this case the tyres are bored out coned on the inside as shown in fig. 19. Again, wrought iron is specified for the boss and washer plate, but these may be made of cast steel if preferred. Until recently cast iron was largely used for the bosses and plates, but modern practice is in favour of wrought iron or cast steel.

Wheel Balancing.—The clause in the specification relating to the balancing of the wheels is a very important item, as unless this is properly done the easy riding of the carriages will be affected, and an additional tendency given to wearing flat places in the tires. Nearly one-half of the finished wheels manufactured are found on testing to be out of balance, even though every care be taken, owing to the variation in the density of the material, and in practice weights differing up to about 2 lb. are necessary to be attached near the periphery to give the required balance. These weights usually are in plate form and placed under the retaining-ring bolts as shown at B in fig. 17, or screwed to the teak centre just below. The centrifugal force exerted by the unbalanced part of the wheel may be determined by the formula:

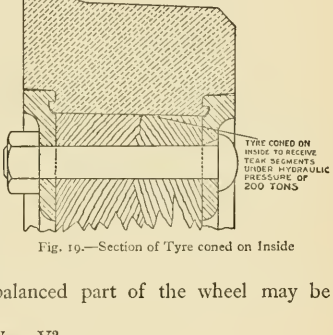


Fig. 19.—Section of Tyre coned on Inside

$$F = \frac{W}{G} \times \frac{V^2}{R},$$

where F = force in pounds,
W = weight of unbalanced portion,
V = uniform velocity in feet per second,
R = radius in feet of the circle described by W,
G = acceleration due to gravity 32·2.

The standard strengths of axle and tyres as now specified for the modern wheel are much more the outcome of many years of practical experience than of scientific calculations, and although the latter, based on accredited data, may be a guide in designing, the heavy and varied strains thrown upon wheels and axles at high speeds render calculations on strengths very complicated, and a high factor of safety must always be allowed.

The Kitson Wheel.—Various ideas have from time to time been brought out to improve upon the Mansell type of wheel for carriages, but, although the patent expired many years ago, this kind of wheel is still most extensively used.

A wheel patented by Mr. W. H. Kitson, of Leeds, and known as a solid disc-cushioned wheel, is illustrated in fig. 20, and this has been used by several companies, the wheel shown in the illustration being of the design adopted on the Waterloo and City Railway. This wheel was invented to

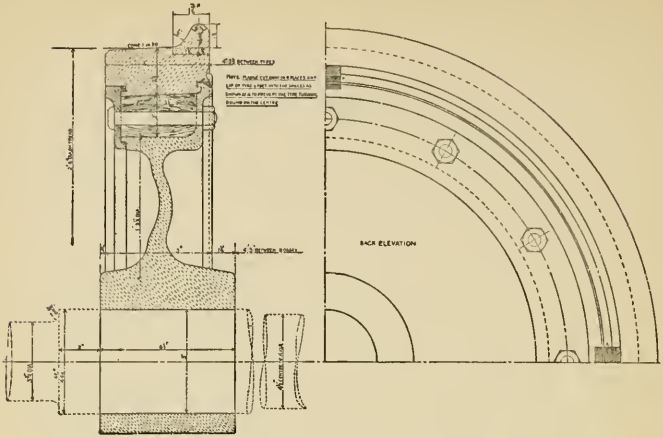


Fig. 20.—Kitson's Patent Cushioned Wheel for Trailer Car (Waterloo and City Railway)

embrace the advantages of a wood cushion between the tyre and centre, and at the same time to use as little timber as practicable, owing to the inevitable

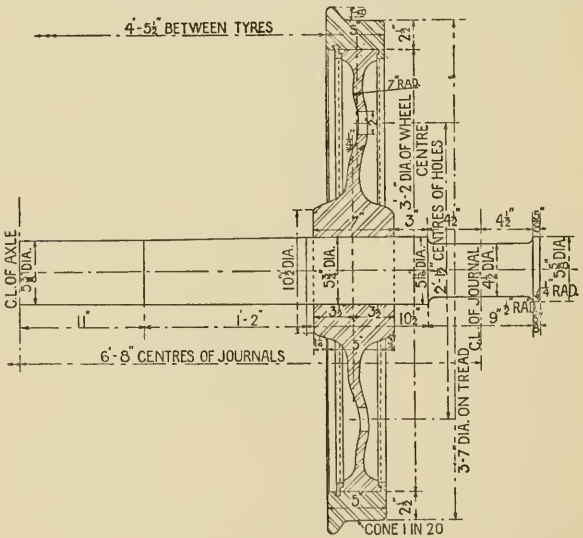


Fig. 21.—3 ft. 7 in. Diameter Carriage Wheel with Steel Disc Centre 9 in. × 4½ in. Journal

shrinkage of the latter. The disc centres of these wheels are made of mild steel with tensile strength of 28 to 32 tons.

Steel disc carriage wheels without any wood cushion between the centre and tire as mentioned above are now being extensively used for new carriages, as, owing to the increase of weight of the latter and greater speeds, the braking effort has necessarily been made higher, rendering the heating of tyres more likely to occur. This applies particularly to electric suburban stock, where speeds are relatively high and stoppages frequent. The motor bogie wheels

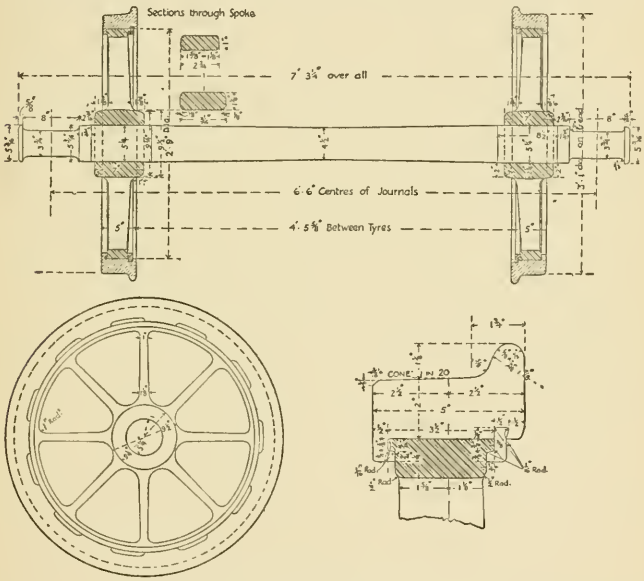


Fig. 22.—Wheel and Axle for Private Owners' 8- and 10-ton Wagons

have always steel disc centres (or wheels of the Schoen type), and experience has shown that the trailer cars should also have similar wheels. An illustration of the latest design for such wheels is shown in fig. 21, and it may be noted that the journals are 9 in. by 4½ in. with axles 5⅜ in. diameter at centre, making them suitable for new type heavy carriages weighing about 36 tons. The "Schoen" wheel mentioned is of American introduction, and the particular feature is that the centre and tyre are forged and rolled in one solid piece without joint or weld.

Iron Wheels.—The next illustration (fig. 22) is a standard wheel for 8- and 10-ton wagons, as specified by the Railway Clearing House for private owners' trucks. In this case the centres are of wrought iron with

solid spokes, but the open spokes similar to those illustrated in fig. 23 are allowed to be used if preferred. The bosses are of wrought iron, and although until recently wagon wheels with cast bosses were permissible, this clause has now been withdrawn, as it was considered that the very small saving effected by using cast bossed wheels was not commensurate with the possibility incurred of serious damage resulting from a boss cracking or splitting.

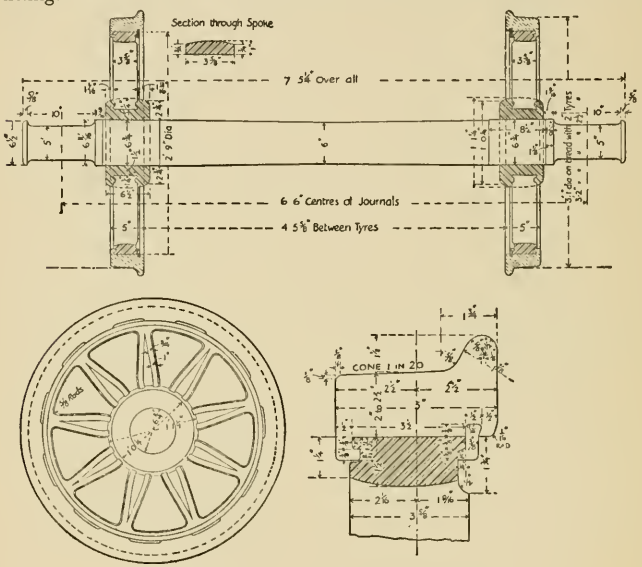


Fig. 23.—Wheel and Axle for Private Owners' 20-ton Tank Wagon

The specifications for the tyres and axles of wagon wheels are similar to those given for the carriage tyres and axles, and to avoid repetition only the exceptions are appended.

1. In the falling-weight test for wagon tyres, the deflection to be 1 in. for every 8 in. of internal diameter.

2. In the falling-weight test for the axles, the distance apart for the bearings and the heights to fall as are follows:

Size of Wheel.	Distance apart of Bearings.	Height of Fall in Feet.
For 8-, 10-, or 12-ton axles, fig. 22	3 ft. 6 in.	20
„ 15- and 30- „ „	3 „ 6 „	22
„ 20- „ „ „ 23	4 „ 0 „	30

3. The tensile test piece for the axles to be 3 in. long, and the sums of the breaking strength in tons and elongation per cent to be not less than 60. The elastic limit must not be less than 50 per cent of the ultimate tensile strength.

The wheels are in all cases forced on the axles by hydraulic pressure, the figure for 8- and 10-ton wheels being not less than 50 tons, and for the 12-, 15-, 20-, and 30-ton wheels not less than 60 tons. These pressures refer to wheels when untyred, but if forced on after tyring, 10 tons extra pressure is required in all cases. The actual pressure exerted to be recorded by being stamped on the axle behind the boss.

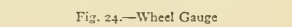


Fig. 24.—Wheel Gauge

Wheel Gauges.—Before concluding the part of this chapter dealing with wheels, it is necessary to illustrate two very important gauges used in the wheelshops and by the inspectors and examiners at out-stations.

The first, and perhaps more important, is the gauge shown in fig. 24 for determining whether the wheels are the proper distances apart on the axles, and if the latter are bent whilst vehicles are in traffic. The second is a female gauge of the flange and tread (fig. 25), which is used to determine whether the tyres have been accurately turned up to the proper profile, and also to give the out-station staff a ready means of seeing quickly the amount of wear which is taking place on the tyres. To detect if the flange has become worn below the minimum allowed of $\frac{7}{8}$ of an inch thickness at $\frac{9}{16}$ in.

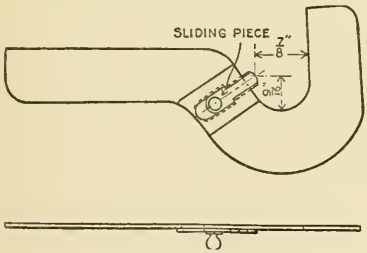


Fig. 25.—Hand Tyre Gauge

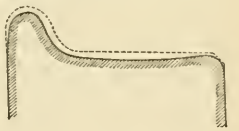


Fig. 26.—Profile of Badly Worn Tyre

from the toe, a small sliding piece is attached to these gauges, as shown in the illustration. In fig. 26 is illustrated the profile of a tyre when badly worn, and when they are in this condition the wheels are placed in a lathe and the tires re-turned up, provided, of course, that the minimum thickness of $1\frac{1}{4}$ in. for re-turned tires is not encroached upon.

Axlebox Design.—A good design of axlebox is a very essential feature of a railway carriage or wagon, and although a great variety is in use on British railways—many differing only very slightly in detail—a general idea of modern practice will be conveyed by the following illustrations and descriptions.

The majority of axleboxes are made of cast iron, and for use on carriages which are seldom subjected to rough shunting this metal gives fairly satis-

factory results. For wagons, however, which have to stand much heavier wear and tear cast-iron axleboxes have proved quite unequal to their work, and in recent years (no doubt owing to the abnormal conditions prevailing during the European War and since) the percentage of breakages has greatly increased. It must be borne in mind that all castings may have the defects of " blow-holes " and unequal sections owing to the movement of cores, and, if they get a sharp knock from the axle, breakage is probable. Very heavy expenditure is incurred for replacements, and much inconvenience and delay to goods in transit by these axlebox failures.

Until recently the only alternative to cast-iron boxes was cast steel or those made from thin pressed steel plates riveted together. The former ones, although much stronger, are considerably more expensive and liable to the defects of all castings, and the latter kind have not been very generally adopted, as they are found under certain conditions to corrode and rust away in a few years.

The latest and as yet best construction for wagon axleboxes are those made from wrought-iron or mild-steel drop forgings electrically welded together, which method of manufacture was brought out in 1918 and patented by Mr. A. Shepherd, of Eastleigh, and an illustration of them is given later in this chapter. Axleboxes made under this process are necessarily even in section and perfectly square and true, the latter being an important factor in the avoidance of hot bearings. As these axleboxes can be made from scrap wrought iron they are not expensive, and the London and South-Western Railway Company has made many thousands of them from this material, and has had no failures in use. It is probable that this type or cast-steel ones will become in general use for new wagon stock in the near future.

Grease was the general lubricant for wagon axleboxes for many years, and it is not very long ago that even carriages on branch lines might be seen in traffic with grease axleboxes. A notable exception to this, however, was the London and South-Western Railway Company, which adopted oil for both carriage and wagon stock over thirty years ago. Modern practice is all in favour of oil lubrication; practically all carriage stock and a large proportion of modern wagon stock are now running in oil. A recent order is that private owners' loaded wagons which are lubricated with grease must not be attached to any goods train which runs more than 30 miles without stopping, the need for this regulation having arisen through the large number of hot axleboxes on such trucks in the past.

Under the latest Railway Clearing House private owners' specifications, the only new wagons now allowed to be registered with grease boxes are 8- and 10-ton ordinary, and 12- and 15-ton tip wagons, and possibly the time is not far distant when new wagons of the former class will have to be fitted with oil axleboxes. Tip wagons have also been fitted with oil boxes of the design shown in fig. 32, and the lubrication in this case is effected by the boxes being packed with waste saturated in oil. Oil lubrication gives much less danger from overheated journals than grease, as the oil, being drawn up from the bottom of the box through the pad, has less likelihood

of conveying grit and dirt between the bearing and journal than is the case with grease fed from a top chamber through holes in the brass. Again, the friction with a high-class lubricating oil is probably only one-half that experienced with grease, particularly in very cold weather; and although a grease film between brass and journal is thicker than an oil film, this point in practice has proved negligible.

In general, to obtain good results and immunity from hot journals everything depends upon: (1) the frames being true and square, (2) the bearings being of the best quality and properly fitted, (3) the quality of the lubricating oil, (4) the boxes being of a good design and quite dustproof, (5) the journals being well finished, and (6) the most careful and constant attention by the staff.

Bearings made wholly of brass are now almost entirely superseded by those of brass lined with white metal. Many well-known mixtures of white metal are on the market, and in use by various railway companies; but without going separately into the composition of each of these it may be stated that, in round figures, the averages taken from four leading kinds gave results as follows:

	Per cent.
Tin	55
Lead	32
Antimony	11·5
Copper	1·5
	100·0

Several railway companies mix their own white metal, and the amount of tin used in the composition varies considerably; but in one case as much as 80 per cent is adopted, with of course a corresponding decrease in the percentage of lead.

Axle Oil.—The oil used for lubrication on British railways varies much in quality, as will be seen from the fact that the price paid by the different companies ranges from 6*d.* to 5*s.* 6*d.* per gallon (pre-war figures); but this variation is in large measure due to the class of traffic, kind of stock, and the distances and speeds travelled. It is a common practice where the stock is heavy, and the distances run without stoppage fairly considerable, to use a mixture of mineral and vegetable oil, the percentage of the latter varying from 20 to 50 per cent. One of the largest British railway companies uses a mixture of two lubricating oils (40 per cent of each), with 20 per cent of rape oil, the price respectively being 10¼*d.*, 8½*d.*, and 2*s.* 4*d.* per gallon (pre-war figures). Details of the analysis of this carriage-axlebox oil will be found on p. 130.

For the purpose of axle lubrication, the oil used should in general possess the following qualifications: (1) It must not be readily decomposed by heat; (2) it should be sufficiently fluid, so as not to cause in itself a bearing to run hard, but not so thin as to be squeezed out between the bearing surfaces; and (3) it must not gum or dry when exposed to the air. From these salient points it will be seen that viscosity or body is one of the most important

DETAILS OF ANALYSIS OF CARRIAGE-AXLEBOX OIL

Analysis.	Lubricating, 10¼*d.* per gal.[1]	Lubricating, 8½*d.* per gal.[1]	Rape, 2*s.* 4*d.* per gal.[1]
Viscosity at 60° F. (water at 60° F.)	53·02	33·14	17·29
Viscosity at 140° F. (water at 60° F.)	3·93	3·55	3·4
Reduction in viscosity on heating from 60° F. to 140° F.	92·6 per cent	89·3 per cent	—
Flashing point (close test)	394° F.	398° F.	—
Congealing point	28° F.	21° F.	—
Free fatty acids	—	—	3·6 per cent
Specific gravity at 60° F.	0·895	0·92	0·9145
Reaction	Neutral	Neutral	—
Colour	Brownish green	Dark red	Light yellow
Clearness	Opaque	Clear	Trace of Turbidity

properties in the value of a good lubricating oil, and considerable attention should be given to the testing and analysing of oil intended for the lubricating of railway rolling stock.

Pressure on Journals.—Earlier in this chapter the amount of weight on the nominal area of a journal was given at about 300 lb. per square inch, but in considering this the actual area of journal in contact with the bearing must be taken into account, and modern practice (as will be seen on reference to the drawings) gives in cross section an angle varying from 70 to 90 degrees, averaging about one-fifth of the circumference; thus it will be seen that the actual pressure on the area of the surfaces in contact is very considerably more than 300 lb., and frequently runs up to 600 lb. In general it is not advisable for a new bearing to be so fitted as to entirely bed on the journal from side to side to commence with, but to give a slight space at the sides, as shown on the drawings, thereby giving the lubricant a better chance to maintain a film between the bearing surfaces, and in course of time the white metal will gradually conform to the radius of the journal. It is important that the inside shoulders of the journal should not be left square, but that $\frac{1}{8}$ or $\frac{3}{16}$ in. radius be given; otherwise, if the vehicles have to work considerably over curves, it will be found that the sharp edge cuts into the white metal and has a strong tendency to commence heating. Most companies now burnish their axle journals with hard-steel rollers, which have the effect of producing what may be termed a glossy surface, which considerably reduces the friction on the bearing.

In fig. 27 is shown the London and South-Western Company's standard wagon axlebox, and the same design is used for carriages, the only difference being that the top lugs and axleguard grooves are made to suit carriage guards and bogie frames. They are manufactured to Shepherd's patent, the body being composed of four wrought-iron drop forgings electrically welded

[1] All pre-war figures.

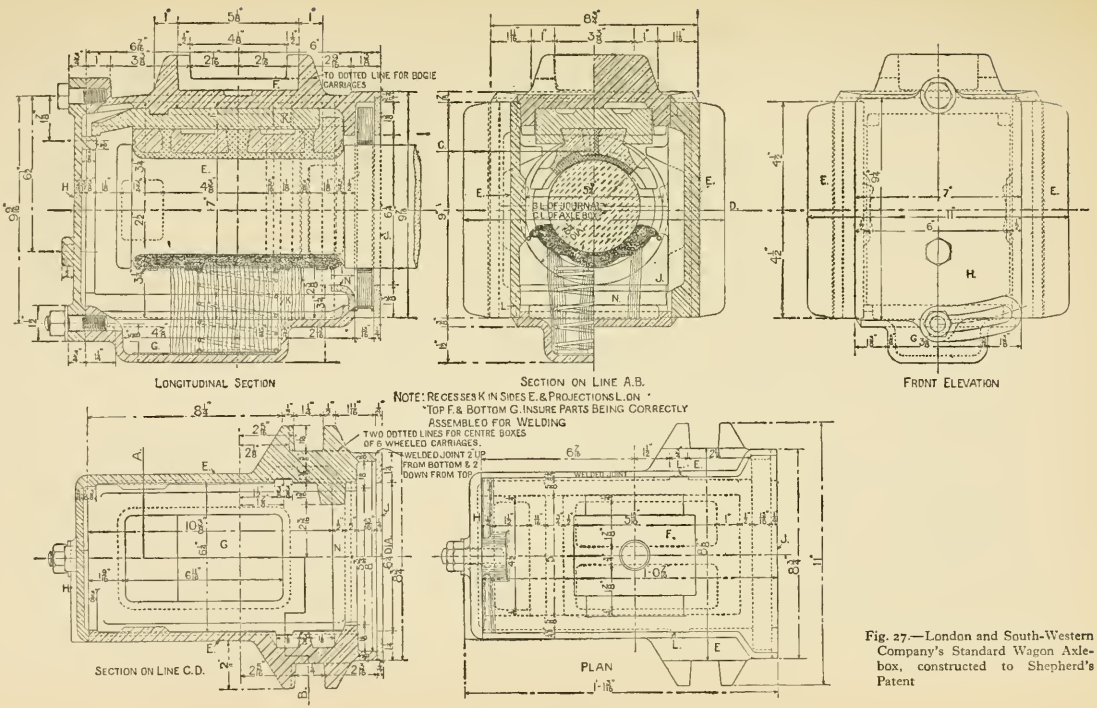

TO DOTTED LINE FOR BOGIE CARRIAGES
LONGITUDINAL SECTION
SECTION ON LINE A.B.
FRONT ELEVATION
NOTE: RECESSES K IN SIDES E. & PROJECTIONS L. ON TOP F. & BOTTOM G. INSURE PARTS BEING CORRECTLY ASSEMBLED FOR WELDING
TWO DOTTED LINES FOR CENTRE BOXES OF 6 WHEELED CARRIAGES.
WELDED JOINT 2" UP FROM BOTTOM & 2" DOWN FROM TOP
SECTION ON LINE C.D.
WELDED JOINT
PLAN

Fig. 27.—London and South-Western Company's Standard Wagon Axlebox, constructed to Shepherd's Patent

together by the quasi-arc process, and the front is also a drop forging. This front is secured by a set screw and stud, and with the provision of a slot at the bottom speedy examination can be made in traffic. With this design of axlebox the changing of a bearing is a matter of a few minutes only, as by the use of a bottle jack under the oil well the box is raised, releasing the slipper and bearing, leaving them free for taking out and replacement. The bearings are lined with $\frac{1}{4}$ in. of white metal, giving a total bearing thickness of $1\frac{1}{4}$ in. The lubrication is effected by the oil being drawn up by capillary attraction through the strands of worsted, thereby keeping the pad continually moist. The pad (which should be soaked in oil for seven days before using) is kept in position by a spring exerting a pressure of about 4 lb., and from time to time it is necessary for this to be properly combed and cleaned in order to prevent a hard top surface forming. The back dust

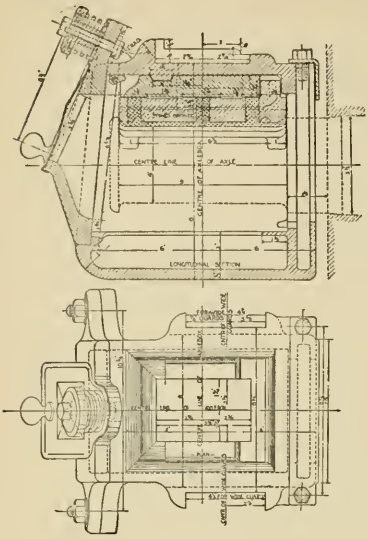
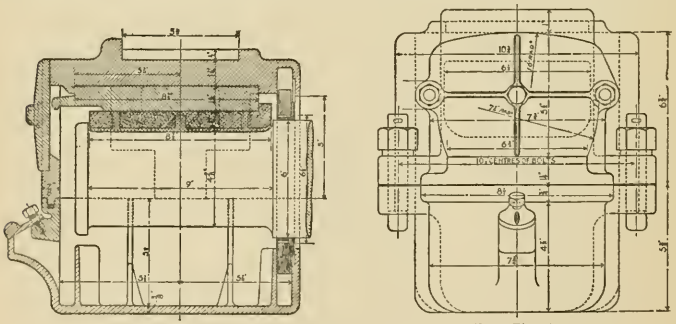


Fig. 28.—London and North-Western Railway Carriage Bogie Axlebox



Longitudinal Section — Front Elevation

Fig. 29.—Great Western Railway Oil Axlebox, 9 in. × 4½ in.

shield is of teak, and lined with leather at the part in contact with the axle.

North-Western and Great Western Standard Axleboxes.—Fig. 28 shows the London and North-Western Company's standard axlebox, and the most distinct feature of this is the addition of an inspection lid provided on the front, which enables an examiner to see quickly the inside condition of a box without using a spanner to slack back the nut on the cast front. In this box the bearing is composed of Stone's bronze lined with white metal, and either waste or Armstrong patent oilers are used to convey the oil lubricant to the journal.

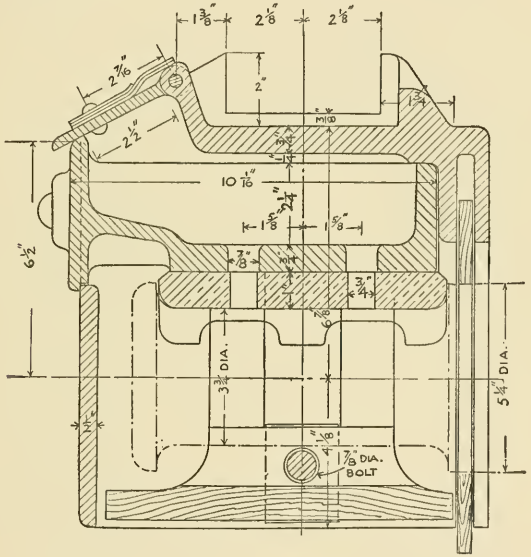


Fig. 30.—Axlebox for Ordinary 8- and 10-ton Wagons. Private owners

The Great Western Company's standard box is shown in fig. 29. this being the box used with the equalizing bar bogie illustrated in fig. 13. It is constructed in top and bottom parts bolted together with two ⅞-in.-diameter T-headed bolts, which are so arranged that the bottom part can be readily detached by merely slacking the nuts so that the heads can be turned round into the slot provided. There is a hinged front to the top portion for inspection purposes, and the front of the bottom half is supplied with a small inlet for the oil feed. The bearing is lubricated from the bottom part by a worsted pad placed therein before bolting up. It will be noticed that in this case the bearing is somewhat lighter than those of the London and South-Western and London and North-Western Companies, and has only $\frac{3}{16}$ in. of white-metal lining, giving 1 in. total thickness. In order to prevent

any waste of oil a groove is made in the lower half, into which a corresponding projection from the top half fits and is bedded upon leather.

Trials are now being made with carriage axleboxes which lubricate the journals without the use of a pad, an example being the " Iracier " box, in which the oil is kept in constant circulation, when travelling, by means of a steel disc fastened by studs to the end of the axle.

Another example is a grease box, the lubricant being in the form of

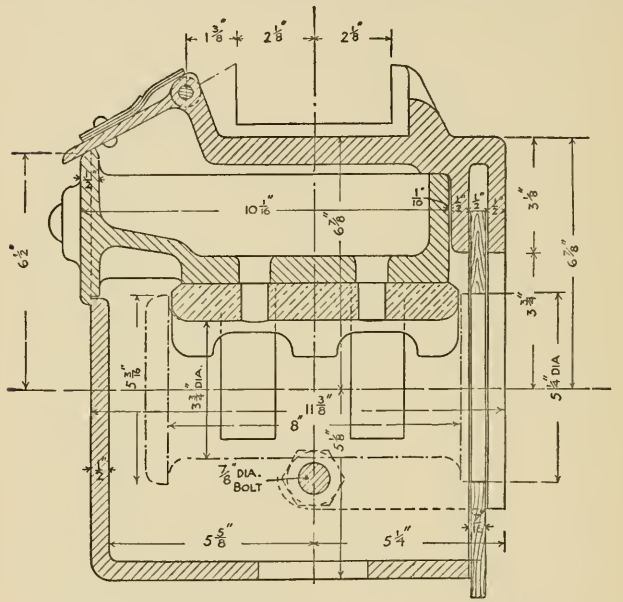


Fig. 31.—Alternative Design for Axlebox of Private Owners' 8- and 10-ton Wagons

a block which is kept in constant contact with the under side of the journal by means of a coil spring. This arrangement is known as " M'Lintock's " axlebox, and so far has given very satisfactory results.

Private Owners' Standard Axleboxes.—The private owners' standard grease axlebox for 8- and 10-ton ordinary wagons is illustrated in fig. 30. The grease chamber is so arranged that it can be easily removed to enable the bearing to be got at for refitting or renewing, and the back of the box is fitted with a wooden dust shield. A $\frac{7}{8}$-in.-diameter bolt passes from side to side under the journal to prevent displacement of the bearing should the wagon be tipped. This class of box is cast open at the bottom and has a wooden " keep " fitted therein, held in position by the $\frac{7}{8}$-in.-diameter bolt mentioned in the previous sentence.

Fig. 31 is an alternative design to that shown in fig. 30, the difference being that the bottom of the box is cast solid, and although slightly heavier, and the cost a little more, it is much less liable to breakage than one with an open bottom.

Fig. 32 illustrates the private owners' axlebox for 12-ton ordinary and 10-ton tank wagons. This box is oil lubricated, and has brass bearings lined with white metal, and the latter is stipulated to be from $\frac{3}{16}$ to $\frac{5}{16}$ in.

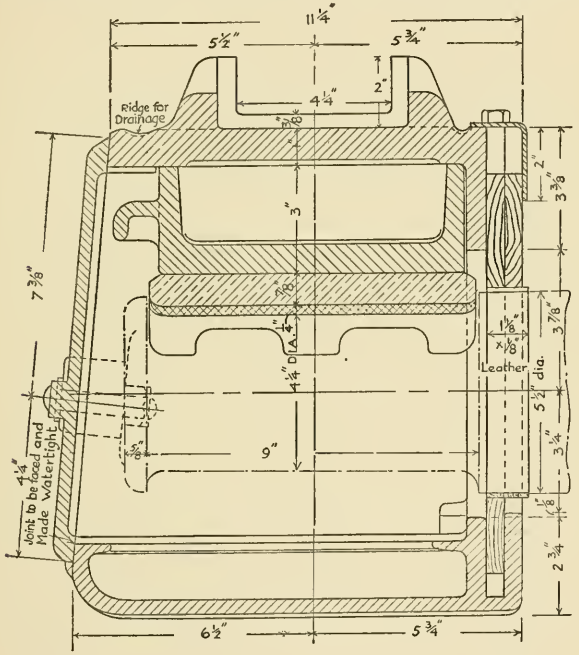


Fig. 32.—Axlebox for Private Owners' 12-ton Ordinary and 10-ton Tank Wagons

in thickness. The slipper is made hollow for lightness, and kept to a depth which will give approximately the same distance from spring seat to centre of journal as in the grease boxes. The oil is carried in the bottom well, as in the carriage boxes already illustrated, and occasionally builders make use of the hollow slippers as auxiliary feeds for lubricant by making small holes through both slipper and brass.

Cast-steel axleboxes are now specified under Railway Clearing House regulations for private owners' 20-ton wagons, and it may be mentioned that of cast-iron boxes for wagons the divided type somewhat after the design

shown in fig. 29 has proved to be less liable to breakage than others. Standardization will no doubt in a few years be applied to all essential details such as wheels, boxes, springs, buffers, drawbars, &c.

CHAPTER VI

Springs and Ironwork Details

The satisfactory riding of a coach depends largely upon the design of the bearing springs, and every care should be taken with this point and to see that the quality of the material used and the workmanship put into the springs are of the best. Before going further, the writer considers it expedient to append the following specifications for laminated bearing springs and volute and helical springs. These give average practice and embody much useful information, and will be found handy for reference.

Specification for Laminated Bearing Springs.—The spring plates shall be manufactured from acid open-hearth or acid Bessemer steel made from the best selected material, and shall contain not less than 0·5 or more than 0·8 per cent of carbon. The steel for bars which have to be welded shall contain not less than 0·45 or more than 0·7 per cent of carbon. The steel, when rolled, must be perfectly smooth on its surface, free from defects of any kind, and true to section. A concavity of $\frac{1}{64}$ in. each side will be allowed in the rolled bars.

Three per cent of the bars used must stand the following camber test. A length of 30 in. to be cut from each bar selected for test. This length to be heated and bent to a curve of a radius equal to eighty times the thickness of the plate, then hardened and tempered. The camber to be measured after the plate has been pressed straight once, after which it must be pushed straight six times in quick succession without showing any permanent set. All plates shall be carefully hardened and tempered. The springs to be of the best workmanship throughout; the plates properly fitted, and touching at the extremities only before the buckle is put on.

Each spring to be tested by a quick-acting scrag before the buckle is put on to an amount equal to $\frac{L^2}{900t}$, where L is the length of the top plate in inches, when straight, and t is the thickness of the plate in inches. They must then stand being deflected again three times in quick succession without showing any permanent set. Each finished spring shall be carefully weighted to determine the range and deflection per ton.

The plates are to receive one coat of boiled linseed oil or crude petroleum before being put together, and the maker's name and date of manufacture must be legibly stamped on each back plate whilst hot and on the buckle.

The buckles must be made of good fibrous bar iron having a tensile

strength of not less than 20 tons or more than 24 tons per square inch, or of mild steel having a breaking strength of not less than 24 tons nor more than 30 tons per square inch. The elongation in each case not less than 20 per cent measured over a parallel length of 8 in. The material should also admit of bending when cold, as follows, without showing crack or flaw:

For iron $\frac{3}{4}$ in. thickness,	through	an angle of	120	degrees.
For iron $\frac{5}{8}$ in. thickness,	,,	,,	130	,,
For iron $\frac{1}{2}$ in. thickness,	,,	,,	140	,,
For steel (all thicknesses),	,,	,,	180	,,

In all cases the inside radius of the bend shall not be greater than one and a half times the thickness of the test piece.

Finished buckles shall be tested to destruction at the rate of 1 per cent as follows: Taper blocks shall be forced through the buckle, straining the metal at both sides and ends. Should the buckle selected part at the weld or break in an unsatisfactory manner, other buckles up to 5 per cent shall be taken, and the bulk represented duly passed for use if the fractures of these are found to be satisfactory.

Specification for Volute and Helical Springs.—The springs shall be manufactured from the highest quality of acid open-hearth or acid Bessemer steel made from the best selected material, and must not contain more than 1·3 per cent or less than 0·8 per cent of carbon. The steel, when rolled, must be perfectly smooth on its surface, and free from defects of any kind, and true to section.

Each spring shall be tested by being driven home once in a scrag and the height then carefully noted. The spring must then stand being driven home again five times in quick succession without showing any permanent set. The springs shall also be tested under ranging loads to determine the range and deflection per ton, up to 5 per cent being usually so treated.

All springs shall be hardened in oil and tempered in a bath of molten lead.

The workmanship shall be of the highest character, care being taken, when coiling, that the coils are uniformly spaced and none of them in contact. Any spring standing under the specified height or more than $\frac{1}{8}$ in. over will be rejected.

Each spring shall be stamped with the maker's name and date of manufacture.

General Design of Springs—Formulæ.—In designing springs for rolling stock it must be borne in mind that the flexibility of a spring varies as the cube of its span and the cube of the thickness of the plate forming it; consequently thicker plates are more necessary for long springs than for short ones. In estimating the load to be carried by each bearing spring, care must be taken to deduct from the total weight of the vehicle the weight of the wheels and axles, axleboxes, and the springs themselves, and to so arrange for the camber of the spring in position to be such that it will give the requisite normal buffer height from the rails to each vehicle when unloaded.

Carriage springs give the best results in riding when they are so designed as to be brought nearly straight when the vehicle is loaded, but in no case should the spring get beyond straight, as if this occurs it soon becomes crippled and the riding unsatisfactory. For passenger-carrying vehicles the springs should be as long as practicable.

Considerable experience is necessary in designing springs if the best results are to be obtained, but D. K. Clark's formulæ for rolling-stock springs given below will be found useful, and will give figures very near actual test results, provided the steel is of the best quality and the workmanship sound and good.

Let B = breadth of plate in inches.
„ D = deflection in inches per ton of load.
„ L = safe load on spring in tons.
„ T = thickness of plates in sixteenths of an inch.
„ N = number of plates.
„ S = span of spring in inches (loaded).
„ C = constant for N = 11·3.
„ *c* = „ D = 0·104.

Then

$$L = \frac{BT^2N}{11{\cdot}3S}, \quad N = \frac{11{\cdot}3SL}{BT^2}, \quad \text{and } D = \frac{0{\cdot}104S^3}{T^3BN}.$$

The writer has found from experience that the constant C for N is more in accord with recent practice at 13 than 11·3, and for *c* for D 0·107 gives the best average results.

Some companies make the top or " back "plate thicker than those forming

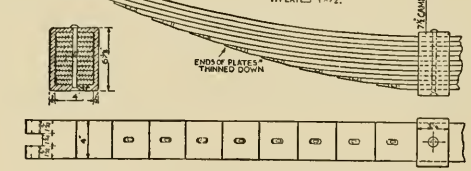


Fig. 33.—7-ft. Side Bearing Spring for Six-wheeled Vehicle

the remainder of the spring, and in calculating for such springs they must be taken as plates and parts of plate all of equal thickness, i.e. supposing a spring to have seven plates 4 in. by $\frac{1}{2}$ in. and two plates 4 in. by $\frac{5}{8}$ in., the $\frac{5}{8}$-in. plates must be replaced in the formulæ by an equal number of $\frac{1}{2}$-in. plates in the ratio of the square of their thickness inversely. In the example quoted, the squares of the thickness of the plates give 3·125, which, added to the seven plates, gives ten and one-eighth plates $\frac{1}{2}$ in. thick. The practice

of using springs made of two thicknesses of plates is not to be commended if easy riding is particularly desired.

To find the radius of the top plate of a spring, having given the dimensions and camber unloaded, the following formula may be used:

Let L = half the chord of the arc in inches.
,, R = radius.
,, C = versed sine or camber of top plate in inches.

Then

$$R = \frac{L^2 + C^2}{2C}.$$

Theoretically each plate of a spring should taper uniformly from the full thickness at the buckle to a thin edge at the end, in order that it may straighten correctly under load, but in practice this is seldom carried out owing to the trouble and expense involved, and to meet the case as nearly as possible it is usual for carriage springs to have the end of the plates either drawn down as shown in fig. 33, or spear-pointed and drawn as shown in fig. 34.

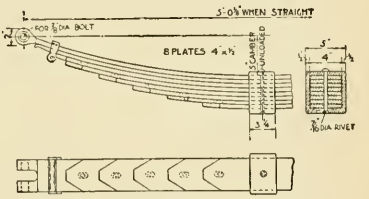


Fig. 34.—Side Bearing Spring for Bogie Vehicles

Illustrated in fig. 33 is a 7-ft. carriage side spring for a six-wheeled vehicle, and these are about the

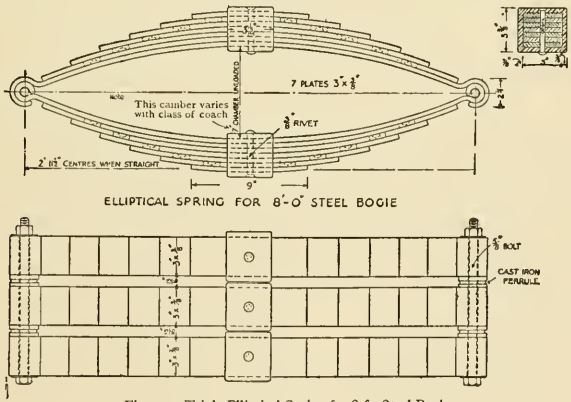


Fig. 35.—Triple Elliptical Spring for 8-ft. Steel Bogie

longest springs in use under English railway stock. Fig. 34 shows the side bearing spring of a long bogie carriage, and fig. 35 a nest of elliptical

springs, similar in design to those used under the bolsters of the bogie illustrated in fig. 13, p. 114. The Railway Clearing House standard private owners' wagon bearing and buffing springs are shown in figs. 36 and 37,

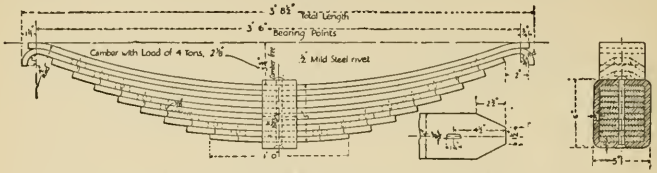


Fig. 36.—Bearing Spring for Private Owners' 12-ton Wagon

and, as the drawings are fully dimensioned, no further written particulars are necessary.

Helical and Volute Springs.—In designing helical and volute springs for railway vehicles, it is necessary to give great consideration to the sudden

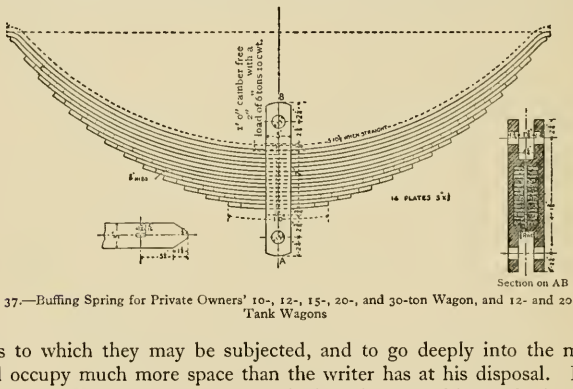


Fig. 37.—Buffing Spring for Private Owners' 10-, 12-, 15-, 20-, and 30-ton Wagon, and 12- and 20-ton Tank Wagons

shocks to which they may be subjected, and to go deeply into the matter would occupy much more space than the writer has at his disposal. However, the following formulæ when designing give very fair results in actual practice, providing the material is up to the quality specified for helical springs as given earlier in this chapter:

Let E = modulus of elasticity in tons, say 16,000.
„ R = mean radius of spring in inches.
„ I = moment of inertia of section of spring.
„ D = diameter of steel, if round, in inches.
„ *b* = breadth of rectangular or square section in inches.
„ *d* = depth of rectangular section in inches.
„ F = deflection of spring in inches.
„ T = modulus of torsion (about ⅜ E), say 5300.
„ *n* = number of revolutions of spring.
„ W = working load in tons.

Then

$$W = \frac{3D^3}{R} \text{ for round steel} = \frac{4{\cdot}72b^3}{R} \text{ for square steel, and}$$

$$= \frac{6{\cdot}67b^2d^2}{R\sqrt{b^2+d^2}} \text{ for rectangular steel.}$$

Then

$$F = \frac{R^3W2\pi n}{IT} = \frac{64nWR^3}{TD^4} \text{ for round steel}$$

$$= \frac{R^3W12\pi n}{Tb^4} \text{ for square steel} = \frac{R^3W(b^2+d^2)6\pi n}{Tb^3d^3} \text{ for rectangular steel.}$$

These formulæ refer to helical springs, but may be applied approximately to volute springs. The deflection of the latter is, however, not proportionate to the load, the resistance increasing rapidly towards the end of the range, i.e. as the spring comes nearer home. The section of a volute spring should gradually and uniformly diminish from the base to the apex, and the offsets should vary as the cube of the radius R.

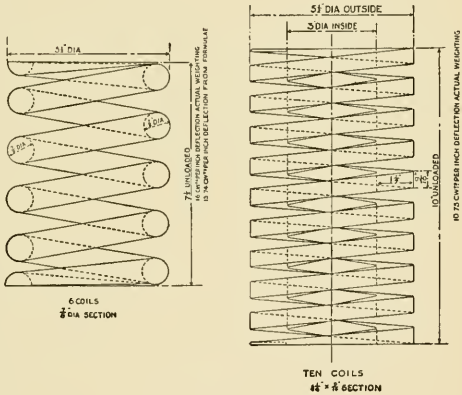


Fig. 38.—Helical Bolster Springs

The writer has found that in applying the above formulæ to helical springs of circular section the theoretical figures more nearly agree with practical tests if one coil is deducted to allow for the necessary tapering of section of the steel to give a flat base. For rectangular or square section the full number of coils may be taken.

In fig. 38 are shown two examples of helical bolster springs, with the actual test weighting given to each, and also the figures as they result from applying the formulæ quoted.

Indiarubber Springs.—Indiarubber springs are now extensively used in carriage and wagon work, both for auxiliary bearing and buffing purposes, and a specification for the highest quality of these articles and the usual tests are appended.

Specification.—The indiarubber to be of the best quality of raw rubber. No old or previously manufactured material to be used, nor any rubber substitutes, nor any hydrocarbon other than indiarubber.

All the indiarubber springs to be thoroughly vulcanized, and to be capable of enduring a dry-heat test of 270° F. for one hour, and a moist-heat test of 320° F. for three hours, without impairing the quality of the rubber.

Each spring must be guaranteed to stand the following mechanical tests, applied both before and after the dry- and moist-heat tests referred to above:

1. The plain indiarubber spring pads to be compressed to half thickness, and the load producing this deflection noted. The proof load so ascertained should not be less than 1 ton for every 3 sq. in. of area. Spring pads with loose plates will be subjected to a specified proof load, and the deflection produced by this load should not be more than one-third, or less than one-fourth, the thickness of the indiarubber.

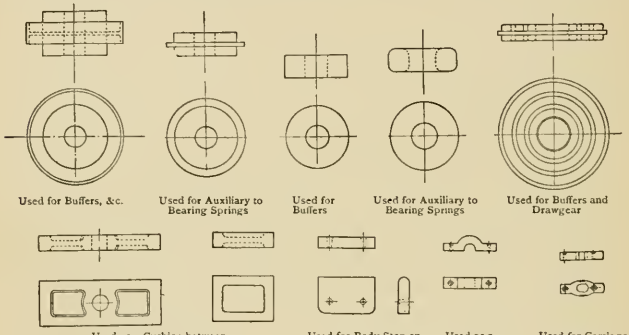

Used for Buffers, &c.
Used for Auxiliary to Bearing Springs
Used for Buffers
Used for Auxiliary to Bearing Springs
Used for Buffers and Drawgear
Used as a Cushion between Body and Underframe
Used for Body Stop on Ends of Coaches
Used as a Rest for Carriage Windows
Used for Carriage Windows

Fig. 39.—Types of Rubbers used in Carriage and Wagon Construction

2. The springs, whether plain or with loose plates, to be compressed for a period of ninety-six hours to the same extent as with proof load, and must return to their original form within one hour of release. (*Note.*—Some companies only specify screwing up for forty-eight hours.)

3. The springs to be subjected to 10,000 compressions to the same extent as before at the rate of 40 compressions per minute, sufficient time being allowed for the pad to cool between each 500 compressions.

The springs must sustain these tests without showing change of form, abrasion, or fracture, and must give the same static resistance on retesting with the proof load.

Illustrated in fig. 39 are shown several of the principal forms of india-rubber springs used in carriage and wagon construction, but all dimensions are purposely omitted, as the sizes vary according to the work they are required for and the loads they have to carry. If the cast rings and spacing plates are treated with some kind of anti-corrosive paint, it has a tendency to prolong the life of the rubbers.

Ironwork Details.—The very large number and variety of details of wrought iron, cast iron, steel, and brass used in the construction of railway

carriages and wagons render it quite impossible to attempt to illustrate and describe them all, but a few of the more important items will be dealt with below, and dimensioned drawings of these are given for reference.

The past decade has witnessed a great change, and very many economies, in the manufacture of wrought-iron details for both carriages and wagons, the general introduction of drop stamps having practically revolutionized the smithing branch. It may almost be placed on a parallel with the introduction many years ago of wood-working machinery to the bodymaking, finishing, and carpentering branches; and it is likely, with the constant improvement and development in the making of the tools, to affect considerably the production of iron and steel castings in the future. The stamps are in general set up in batteries of two, three, or four, the weights most in use for railway work being 10, 15, 20, 30, 40, and 60 cwt. Not only is the stamped work more cheaply produced, but it is necessarily more uniform and accurate than that formerly made by hand labour, and in many items is of better finish and strength.

In conjunction with these stamps oil furnaces have found much favour, as although the coke furnace is perhaps as economical as regards cost of fuel, the oil furnace is quicker in action, cheaper in use, and forms less scale on the metal heated.

Until recent years no strict uniformity in the buffers, couplings, and drawbar hooks of British carriages had been adopted, consequently these details varied somewhat in shape and dimensions on the various companies' vehicles, and so long as there was little or no interchange of rolling stock no difficulty was experienced. However, the last few years have brought about a great alteration, and through carriages, frequently travelling over four or five different systems daily, are now quite common, and it has become necessary to standardize the projection of buffers, the profile of drawbar hooks, and the size and length of the screw couplings, and to have uniformity in gangways for corridor stock. This matter was duly considered by the Railway Clearing House Carriage and Wagon Superintendents Committee, and appended are the standard dimensions which have now practically been adopted by all companies, and with which the illustrations given hereafter will be found to agree:

	Feet.	Inches.
Normal length of buffer from headstock to face (carriages)	1	10
Normal length of buffer from headstock to face (wagons without continuous brake)	1	6
Normal length of buffer from headstock to face (wagons with continuous brake)	1	8½
From face of headstock to bend of drawbar hook (carriages)	0	8½
From face of headstock to point of drawbar hook (carriages)	0	6¾
From face of headstock to front end of slot (carriages) ..	0	4½
From point of hook to bend of hook (carriages)	0	1¾
Thickness of hook (carriages)	0	1¾
Space for coupling to pass over hook (carriages) (minimum)	0	1⅝
Length of screw coupling when fully extended (carriages) ..	3	1
Length of screw coupling when fully extended (wagons with continuous brake)	2	11

Carriage Drawbar Hooks—Screw Couplings.—Fig. 40 illustrates a standard carriage drawbar hook as used on the London and South-Western Railway Company's carriages, and in this case it will be noticed that although the specified thickness of $1\frac{3}{4}$ in. is adhered to at the part where the coupling pulls, it is tapered to give $2\frac{1}{4}$ in. thickness at the shoulder, the reason for this being that on long vehicles the side strain on the hooks when tight-coupled and going round sharp curves is very considerable. These hooks are made of A-grade iron or mild steel, and stamped out in top and bottom tools either in drop stamps or under the steam hammer.

The next illustration, fig. 41, is a standard carriage screw coupling, and the whole of the parts, except the lever and ball, are made from A-grade quality of iron or mild steel, the former having a tensile strength of from 21 to 24 tons per square inch of area, with an elongation of not less than 25 per cent in 8 in., and a reduction of area of not less than 46 per cent, and the latter a tensile strength of 26 to 32 tons per square inch, with a minimum elongation of 28 to 22 per cent. The shackles are drawn down out of the solid $2\frac{1}{8}$-in.-diameter bar, and the screw is cut from a bar of $1\frac{7}{8}$ in. diameter.

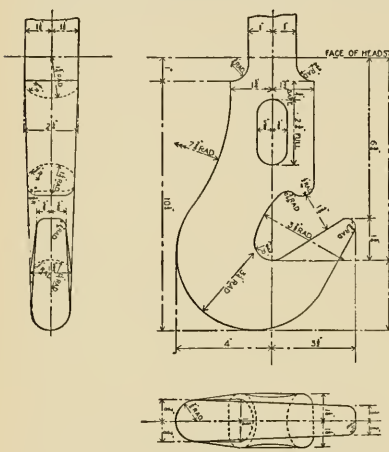


Fig. 40.—New Standard Carriage Drawbar Hook

Some companies anneal all the parts of their drawgear with a view to minimizing the possibility of breakage from the sudden stresses and shocks to which they may be subjected. In such case it is usual to re-anneal them about every five years.

It may here be noted that the British Engineering Standards Committee have issued specifications for wrought iron for use in railway rolling stock, the qualities being designated as " Best Yorkshire " and grades " A ", " B ", and " C ". This is distinctly a step in the right direction, and is welcomed both by the manufacturers of iron and the users thereof, as hitherto few companies issued exactly the same specification for wrought-iron plates and bars. The full specifications No. 51–1913 are published by the Association, and a reader desiring further and full information should make reference thereto.

Buffers, Axleguards, and Scroll Irons. — A carriage buffer designed for use with laminated buffing springs behind the headstock is

shown in fig. 42. These are made in tools, from the best faggoted iron, in a similar manner to the drawbar hooks. The diameter of the head is given

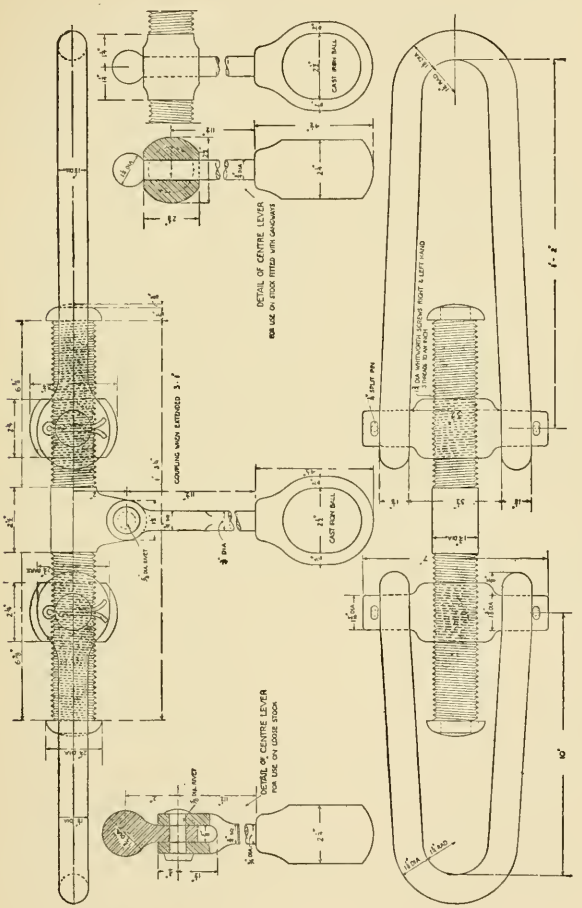


Fig. 41.—New Standard Carriage Screw Coupling

as 16 in., but many companies use an elliptical shape for bogie carriages, the width increasing in proportion to the length of vehicle the buffer is intended for, in order to prevent buffer-locking in going over sharp curves. Fig. 43 shows a carriage buffer for use with indiarubber buffing springs behind the

headstock, and in this case the part to receive the indiarubber springs is turned up in the lathe to the required diameter.

A standard carriage axleguard for six-wheeled and four-wheeled vehicles is illustrated in fig. 44, and the same design is generally used for wagons, with the dimensions modified to suit the vehicle. These guards are made from grade-A iron, the crownpiece being bent to the shape required and the wings welded into the legs thereof afterwards.

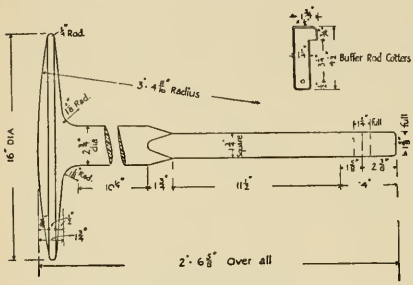


Fig. 42.—Buffer Head and Rod to suit Laminated Buffing Springs

The scroll irons are important items in a six-wheeled carriage, and fig. 45 shows the usual form adopted by many companies, although, if the weight to be carried is not great, the neck may be made of circular section instead of rectangular. It is very necessary that the scroll iron should not spring in working. Forgings made from the best quality of double-faggoted scrap are generally used.

Two forms of brake block connecting bars are shown in fig. 46, the triangular form being more generally used on six- and four-wheeled vehicles and the plain bar for bogie stock. The ends of these bars, all brake pins and other parts which are subjected to constant friction when travelling, should be properly case-

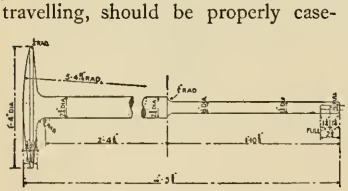


Fig. 43.—Buffer Head and Rod to suit Indiarubber Buffing Springs

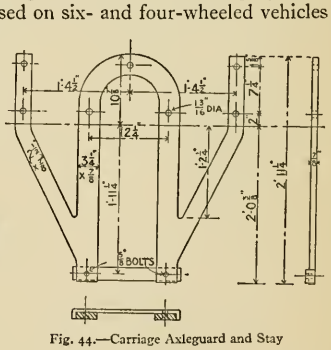


Fig. 44.—Carriage Axleguard and Stay

hardened to minimize wear, and this is done in furnaces specially designed for the work. Great care must be taken in designing brake bars, as if they are not made sufficiently strong they will soon get a permanent deflection at the centre.

Corridor Gangways.—The main dimensions for standard corridor gangways have been agreed to by all companies, in order to facilitate the through working of carriages over different lines. Some companies use

rubber sheets or 3-ply canvas webbing for the flexible portion, but the majority use leather. When a corridor vehicle is running at the end of a train or next the engine, it is necessary that the opening should be covered over to prevent sparks, &c., blowing in, and for this purpose most companies

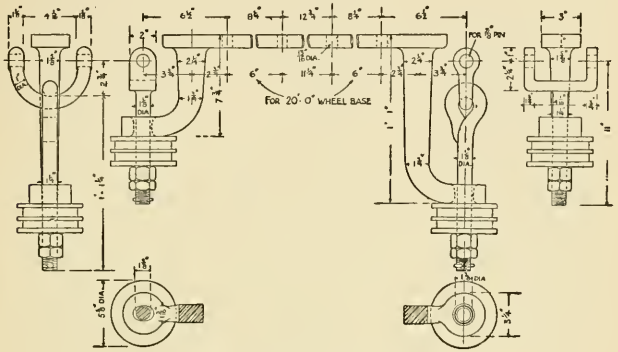


Fig. 45.—Scroll Irons, &c., for Six-wheel Carriages

use a portable wood and canvas shield. As, however, these shields are constantly getting broken and damaged, it has been found much more convenient to have a cover attached to each gangway, and the London and South-Western Company has designed and adopted the arrangement shown in fig. 47.

Drawbar Release for Slipping Coaches. — To enable one or more coaches to be slipped at an intermediate station from a fast train, the drawbar hook is so arranged that the guard may, by pulling a lever, release the coupling at a certain distance from the station at which it is desired to call, and, by a judicious use of the hand-brake, stop where required. The arrangement of the hook and lever, &c., is shown in fig. 48. As it is very essential that the guard should not release the coupling until he has parted the brake cocks (in order to maintain the vacuum in the front portion of the train, and also in the slip vehicle for emergency purposes), an interlocking arrangement is sometimes adopted by which it is rendered impossible for a guard to make a mistake by pulling the

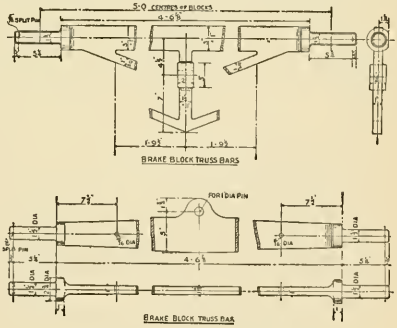


Fig. 46.—Brake Block Connecting Bars

wrong lever. This interlocking gear is clearly shown in the detail, and it is advisable that all such vehicles should be fitted with some safety device of this kind. Slip carriages are not so numerous now as they were a few years ago, and wherever possible the additional stop is made in preference to slipping coaches.

Wagon Drawbar Hooks, Couplings, and Cradles.—There are

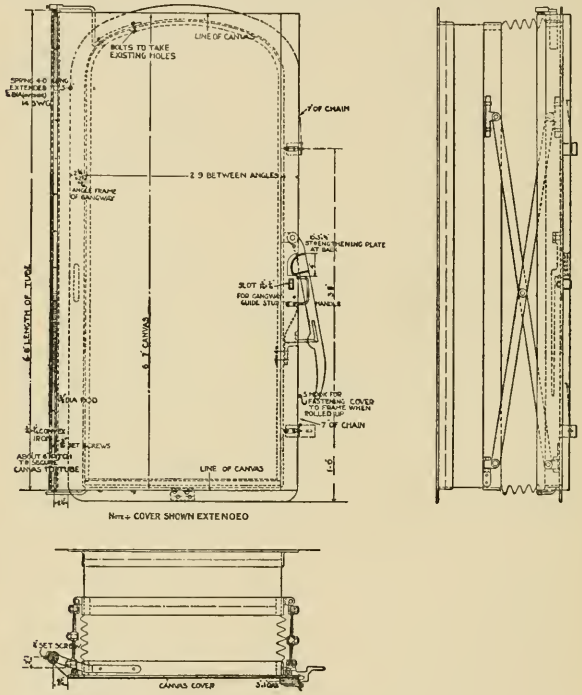


Fig. 47.—London and South-Western Railway Company's Design for Spring Cover as fitted to Standard Gangway

two forms of private owners' wagon drawbar hook, one having Gedge's slot (as shown in fig. 49), and the other made solid with link welded in. When a wagon is not fitted with laminated draw springs, it should be noted that the drawbars have an enlarged part thereon (or a pin put through), thus forming shoulders at a certain distance behind the headstock (see illustration); so that should a drawbar break at its least diameter ($1\frac{3}{4}$ in.) these safety shoulders will strike and pull upon a plate fitted for this purpose on the inside of the headstock, and prevent a train becoming divided when travelling, the latter

being a very serious matter at any time, but particularly so when going up an incline. At one time the railway companies did not think it necessary to maintain exact uniformity in the sizes of hooks, but this has now been altered, and the private owners' wagon standard is generally adopted. The hooks are made from the A-grade iron or mild steel, and stamped out in tools similar to the carriage hooks. The standard wagon coupling chains have three links, and are made from the very best cable iron $1\frac{1}{2}$ in. diameter, and the welds made at the sides. This, however, is not an invariable practice, as some companies have in use weldless steel chains in preference thereto, as, although the cost is somewhat more, the security from the possibility of breaking away is considerably

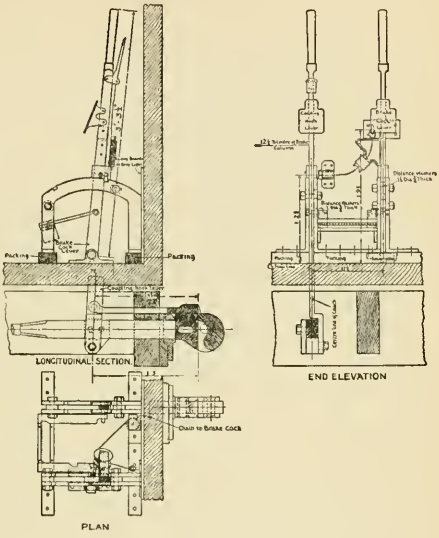
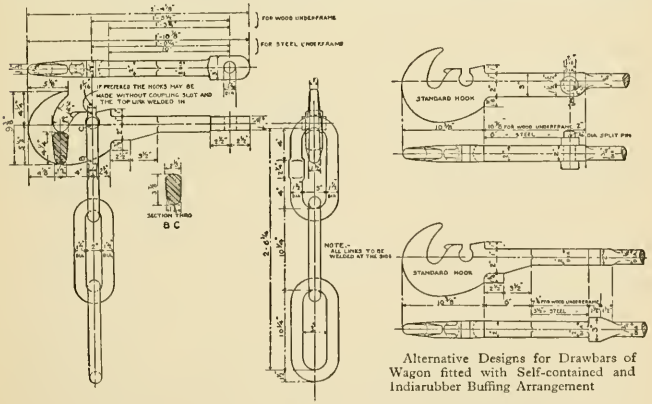


Fig. 48.—Method of Interlocking Brake Cock and Slip Coupling


FOR WOOD UNDERFRAME
FOR STEEL UNDERFRAME
IF PREFERRED THE HOOKS MAY BE MADE WITHOUT COUPLING SLOT AND THE TOP LINK WELDED IN
SECTION THRO B C
NOTE.—ALL LINKS TO BE WELDED AT THE SIDE
STANDARD HOOK
STANDARD HOOK

Alternative Designs for Drawbars of Wagon fitted with Self-contained and Indiarubber Buffing Arrangement

Fig. 49.—Standard Hook and Coupling for Wagons fitted with Laminated Buffing and Draw Springs

increased, owing to the greater strength. Until recent years the three links were all made with 3 in. inside clearance, but owing to the frequent parting of goods trains it was found by careful experiment that if the middle link had only 2 in. space inside there was much less likelihood of this happening, and accordingly the latter figure is now adopted, and all old-pattern couplings are being replaced as opportunity arises. For the same reason a projection has been recently added to this hook as shown on the drawing, the object being to cause the coupling chain to sag quickly, instead of possibly riding up the hook, which may take place on a sudden snatch and recoil. It may, however, be noted that a similar projection has been used by the London and South-Western Railway Company for many years upon their wagon drawhooks, with very satisfactory results.

The latest form and size of wagon drawbar cradle is shown in fig. 50, together with its interior fittings. For many years these cradles were only

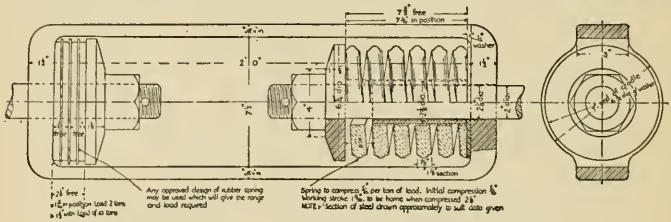

Any approved design of rubber spring may be used which will give the range and load required
Spring to compress ¼" per ton of load. Initial compression ¾"
Working stroke 1⅝", to be home when compressed 2⅜"
NOTE.—Section of steel drawn approximately to suit data given

Fig. 50.—Drawbar Cradle Arrangement with Indiarubber and Steel Springs for Private Owners' 8-, 10-, 12-, 15-, and 20-ton Wagons, and 10-, 12-, and 20-ton Tank Wagons

18 in. long inside, and were fitted either with one indiarubber spring or one coil steel spring as an auxiliary to the laminated buffing spring; but the frequent breakage of couplings and of the coil spring, and the high initial cost of the indiarubber, gave rise to a desire to try a combination of both rubber and steel springs, such as is shown in the illustration, and up to the time of writing this has given very satisfactory results.

Self-contained Buffers.—Where it is not possible, owing to some special interior construction of the underframe, to use a laminated or indiarubber buffing gear behind the headstock, it is usual to adopt what is technically known as a self-contained buffer, somewhat on the lines of those shown in figs. 51 and 52, and of this class of buffer there is a great number of varieties. These are more frequently required in wagons than in carriage stock, and where trucks are designed for carrying acids the use of this class of buffer becomes absolutely necessary. Five examples are given in the illustrations, and it will be seen that indiarubber, steel helical, and volute springs are used, the outer cases being of cast iron, cast steel, or wrought iron as preferred. Much time and thought have been given recently to perfecting this kind of buffer, with a view to its more extensive adoption in the future, as laminated springs not only cause the underframe to be weakened where cut away for their insertion, but are themselves liable to frequent breakage.

The great difficulty, however, which has confronted the designer of self-contained buffer springs is to obtain sufficient strength and range of deflection

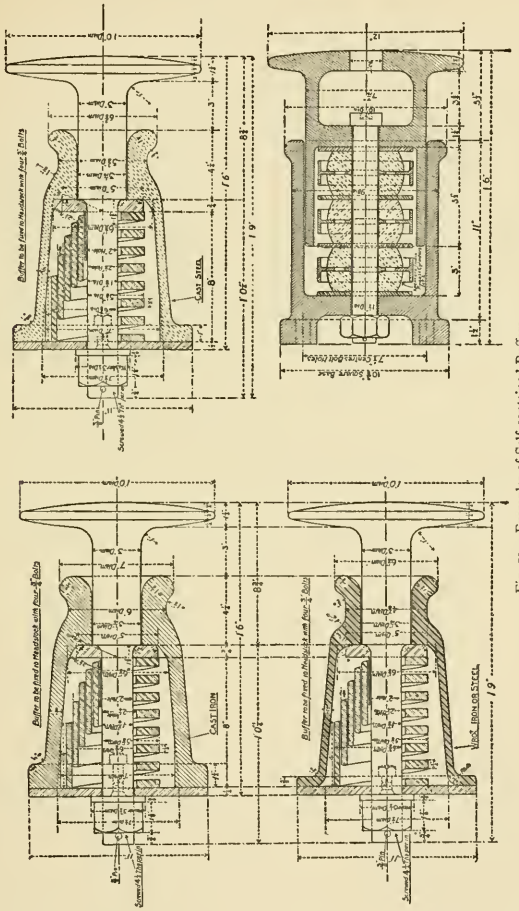


Fig. 51.—Examples of Self-contained Buffers

in the small space available, and the type, fig. 52, shows one of the latest designs, in which a maximum space for a spring has been obtained.

Brake Blocks, &c.—Of other ironwork details used in carriage and wagon design it may be mentioned that carriage brake blocks are usually

made of cast iron, but to obtain greater durability some companies now have these made of chilled iron or of the Sargent diamond type, inset with an expanding metal. To save renewing the *whole* of the block when worn,

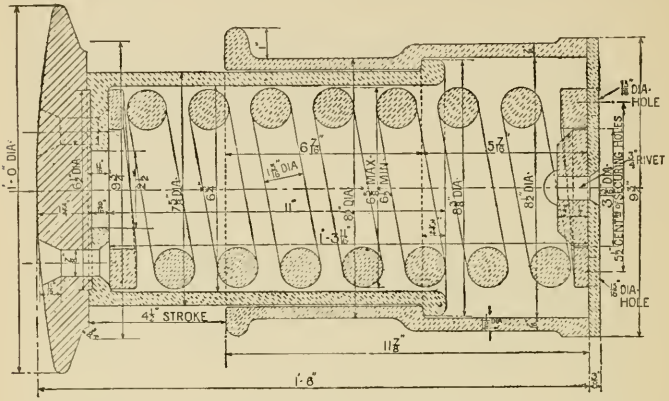


Fig. 52.—Self-contained Buffer with Maximum Stroke

PARTICULARS OF SPRING.—Height at end of stroke = 11 1/16 in. Load at end of stroke = 7 tons 5 cwt. Height free = 1 ft. 4⅛ in. maximum, 1 ft. 4⅛ in. minimum. Height solid = 10¾ in. maximum, 10½ in. minimum. Number of coils = 8. Section of steel = 1 1/16 in. diameter.

several designs of " refill " blocks are now being tried, but at present it is not possible to say whether they will merit universal adoption.

CHAPTER VII

Bodymaking and Type of Bodies

The type of railway-carriage body generally constructed on British railways (that divided into a series of compartments entered by side doors and having transverse seats) gives a maximum seating capacity, and, with the number of doors, allows the passengers to enter and leave in a very expeditious manner. The size of compartments for the ordinary type of coach to a very large extent depends upon the service or traffic the vehicle is intended for. Carriages for main-line services, where the distance travelled is fairly considerable, have somewhat larger compartments than those intended for suburban services, but the following figures will give the approximate length of compartments adopted by the larger companies:

Main-line Stock

First class: from 6 ft. 10 in. to 7 ft. 6 in.
Second class: from 6 ft. to 6 ft. 6 in.
Third class: from 5 ft. 10 in. to 6 ft. 5 in.

Suburban Stock

First class: from 6 ft. 3 in. to 6 ft. 6 in.
Second class: from 5 ft. 10 in. to 6 ft.
Third class: from 5 ft. 3 in. to 5 ft. 9 in.

The body details and building practice vary somewhat on different British railways, but in the following paragraphs the writer has endeavoured to give a general idea of the average practice and dimensions.

General Principles of Design.—In designing carriage bodies, careful consideration must be given to the arrangement of the framing, so as to place it in the best position to meet the stresses which come upon it. A maximum of strength will then be obtained with a minimum of material, and a vehicle of the lowest possible tare will be ensured. The joints should be as simple as possible, so that the parts can be manufactured by machinery, thus reducing the cost of construction, and also the maintenance of the vehicle, by enabling repairs to be effected at a minimum cost. In long bogie vehicles the first-class compartments should, if possible, be placed at the centre of the coach, where the best riding is obtained; and guards' compartments, vestibules, and lavatories situated at the extreme ends. The form and dimensions of the body are governed by each company's maximum loading gauge, but modern stock is built up to the prescribed limits, in order to obtain as much room and air space as possible inside the compartments. The sides of British coaches are generally curved below the waist, this curvature being technically known as a " turn under ", and varying from 2 in. to 5 in., but this depends on the width of body and the maximum distance allowed over stepboards, as it is necessary that a foothold of about 6 in. be given in the doorways, which on wide stock can only be effected by cutting away the bottomsides between the standing pillars.

The curve of the roof varies with different companies, the three principal shapes being segmental, elliptical, and clerestory. The elliptical form is now very largely used, as the clerestory roof (until very recently the standard of several leading companies) was costly both in building and in maintenance. The elliptical form has several advantages over the segmental, notably the considerable increase of air space, and the effective manner in which the weight of the roof can be carried directly on to the side framing, instead of acting obliquely to the sides and tending to force them out, thus causing the roof to sag at the centre and form a series of hollows at the crown. In general the elliptical form is not geometrically true, but is modified to suit tunnels, &c., and this form of roof as most recently adopted is such that the centre is within about 6 in. as high from the rail level as the clerestory formerly was, and gives approximately the same sectional area as the latter.

Carriage Joinery.—Before dealing with the construction of the bottom framing of a coach, it is expedient to illustrate and describe several joints of the main members. Fig. 53 shows an end bar tenoned into the bottomside, and in addition shows how the corner pillar is connected and secured to the bottom framing. The tenon on the end bar is known as

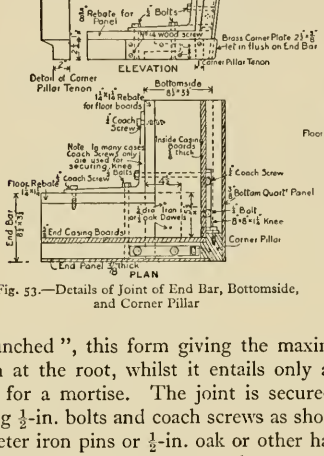


Fig. 53.—Details of Joint of End Bar, Bottomside, and Corner Pillar

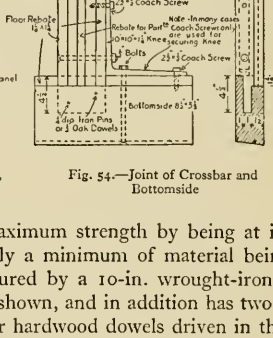


Fig. 54.—Joint of Crossbar and Bottomside

"haunched", this form giving the maximum strength by being at its full width at the root, whilst it entails only a minimum of material being cut away for a mortise. The joint is secured by a 10-in. wrought-iron knee, having ½-in. bolts and coach screws as shown, and in addition has two ¼-in.-diameter iron pins or ½-in. oak or other hardwood dowels driven in through the tenon. In many cases coach screws only are used, but some bolts are preferable, as, should a hole be bored too large or the timber split, the coach screws have a very small holding power upon the timber.

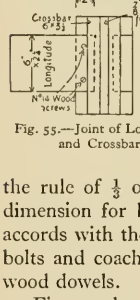


Fig. 55.—Joint of Longitude and Crossbar

Fig. 54 shows a joint of a crossbar or partition bearer with a bottomside, and, owing to the floor rebate in the bottomside being cut by a circular saw from end to end, it is necessary to form the shoulders of the tenons on the crossbar to fill up the space formed by this rebate; hence we get the uneven shoulders as shown. The tenons of the floor framing are 1 in. thick, which does not quite conform to the rule of ⅓ of thickness of material, but a 1-in. tenon being a standard dimension for both 3-in. and 3½-in. bottom framing, in the former case it accords with the rule. The joint is secured by a 10-in. knee, having ½-in. bolts and coach screws, also by two ¼-in.-diameter iron pins or ½-in. hardwood dowels.

Fig. 55 shows a longitude tenoned into a crossbar, and fig. 56 a batten lapped on to a longitude, and as these are fully dimensioned they need no

explanation. Care must be taken that all joints and connecting ironwork are well coated with white lead before being finally fixed together.

Owing to the great difficulties experienced in obtaining timber sufficiently long and free from shakes, and the high cost of such timber, bottomsides for long vehicles are now frequently spliced, and fig. 57 shows such a joint, generally termed a " scarf ". This joint is strengthened by means of $\frac{1}{4}$-in. and $\frac{3}{8}$-in. plates of the length and width shown, and secured by $\frac{3}{8}$-in. bolts, this splice being generally placed under the seat of a compartment and clear of the crossbar tenon; but in the case of corridor stock, where a level surface is required in the corridor, plate A would be let in flush, and countersunk bolts put in the reverse way, so that the nuts will come on the under side.

In constructing the " bottom ", the framing first having been set out and machined in the sawmill, the parts are then dealt with by the body-maker,

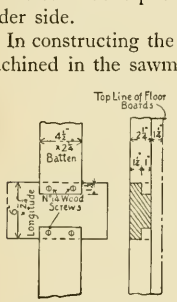


Fig. 56.—Joint of Floor Batten and Longitude

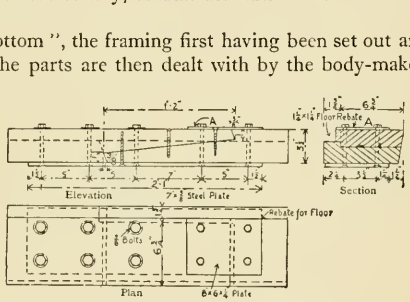


Fig. 57.—Detail of Splice for Bottomside

who cleans out the mortises and does any slight handwork required. Upon the floor of the body shop, and running parallel with the rails, are placed edgeways 9-in.-by-3-in. deals termed " horses ", these being supported at intervals by short pieces of the same section, termed " saddles ", notched out to receive them. Upon the horses are placed transversely 7-in.-by-2$\frac{1}{2}$-in. deals, and on these the prepared bottom sides are placed. The end bars and crossbars are then fitted into their respective mortises with a good driving fit, and the longitudes and interior framework similarly dealt with, the whole being afterwards disconnected, and the joints painted with white lead. The crossbars are now driven into one of the bottomsides, and the interior framework connected therewith, and the remaining bottomside driven on to the tenons. All joints are now drawn together, and the bottom tested for squareness by a diagonal test, i.e. measuring with a staff from each corner pillar mortise, and if the bottom is square, then all the knees can be finally tightened up and the joints secured. Owing to the present length of bodies, some companies prefer to build them resting on the steel underframe instead of the " horses " spoken of above; and, as the frames have an initial camber, this arrangement not only assists to maintain good joints, but is of material assistance in resisting deflection when the vehicle is lifted for the purpose of placing the bogies under.

The bottomsides are next tested to see if they show up quite straight, this being accomplished by means of a chalk line stretched from end to end of the bottomside, the extreme ends being secured against the inside cheeks of the corner pillar mortises, when all intermediate pillar mortises should coincide with the chalk line. Should the bottomsides require straightening, this can be effected by means of struts from the permanent-way rails, these struts being kept in position until the floor boards are cut and securely fastened in their place.

Arrangement of Flooring.—There are several methods of arranging the floor boards. Fig. 58 shows the simplest and least expensive, and the one which is generally adopted for guards' and luggage vans and sometimes for third-class compartments. This consists of one layer of $8\frac{1}{2}$-in.-by-$1\frac{1}{4}$-in. tongued and grooved boards laid transversely as shown, although in some cases the boards are placed longitudinally; but the former method is pre-

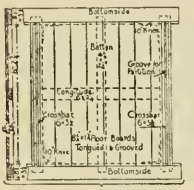


Fig. 58.—Plan of Single Flooring

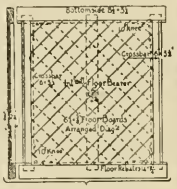


Fig. 59.—Plan of Double Diagonal Flooring

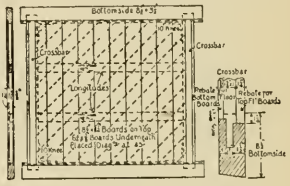


Fig. 60.—Plan and Section of Double Flooring (insulated)

ferable as tending to keep the bottomsides straight and in position. A disadvantage of the foregoing method is that should the boards shrink and the tongues get broken there will be open joints, which render the compartments draughty and the floor unsightly.

Some companies place in their luggage compartments a series of hardwood strips over the top of the floor boards, the object being to protect the deal boards from damage, and to give a better foothold for men when lifting heavy weights. The principal objection to this arrangement, however, is the difficulty in effectually sweeping out the dirt when the vehicles are cleaned.

Fig. 59 shows a method largely adopted for first-, second-, and third-class compartments. Two layers of $\frac{5}{8}$-in. boards are placed in a rebate $1\frac{1}{4}$ in. deep, arranged diagonally at an angle of 45 degrees, the top layer running in an opposite direction to the bottom, and by careful cutting of the boards one cut can be made to serve two joints, by simply reversing the boards, thus saving material and labour. With this arrangement a very strong floor is obtained, due to screwing the two boards together, and all likelihood of draught is prevented, as the top boards break joint with those beneath, and with the boards so arranged they give the most effective method of keeping the whole bottom square. Fig. 60 is an arrangement of flooring for first-class compartments and saloons, and consists of $6\frac{1}{2}$-in.-by-$\frac{5}{8}$-in.

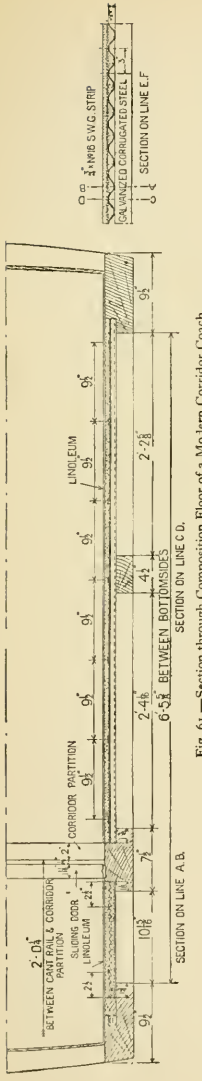


Fig. 61.—Section through Composition Floor of a Modern Corridor Coach

boards on the under side, and $8\frac{1}{2}$-in.-by-$1\frac{1}{4}$-in. boards on the top side, the intervening space being filled with either sawdust, felt, cork, or other suitable material. By this means all possibility of draught entering the compartments at the joints of boards is obviated, and at the same time the packing is considered to act as a non-conductor of sound. In "flooring up", the bottom framing is required to be turned over for the fixing of the $\frac{5}{8}$-in. casing boards, and the arrangement of these diagonally at 45 degrees, and in alternate directions for every compartment, materially assists in keeping the bottom true and square. When the boards have been screwed in, all the joints are levelled off, and the whole given a coat of lead colour. When dry,

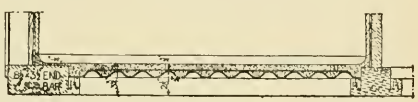


Fig. 62.—Section through Lavatory Floor of a Modern Corridor Coach

the bottom is again turned over and the space filled with either of the packing materials mentioned above. The $8\frac{1}{2}$-in.-by-$1\frac{1}{4}$-in. top boards are then cut and arranged transversely and secured by screws, the whole being afterwards cleaned off and painted as described for the under boards. Care must be taken that all rebates, tongues, and grooves are well painted before being connected together, and due attention given to the springing-in of the floor boards in position, so as to force all boards tightly together and make good joints.

Fig. 61 shows an arrangement of composition floor for railway carriages, and is adopted on account of its fire-resisting and hygienic advantages. The framework of the floor is of the usual construction, but the deal boards are dispensed with and galvanized corrugated steel of No. 16 S.W.G. substituted, with the space between latter and top of framework filled in with materials such as "Sanolit" or "Decolite".

The latter is generally formed of a bottom layer placed in the corrugations to form a foun-

dation for a top layer of finer and more superior material, and galvanized steps $\frac{3}{4}$ in. wide are riveted at about 9 in. pitch to the top corrugations to form the necessary key.

Composition floor material is generally purchased in a powder and mixed with salts or other chemical solutions into a plastic state, and before it is used the steel plates should be given a good coat of special paint to prevent corrosion.

In fig. 62 is shown a section through a lavatory compartment floor, and in this example all timber is covered with the composition, and a coving is

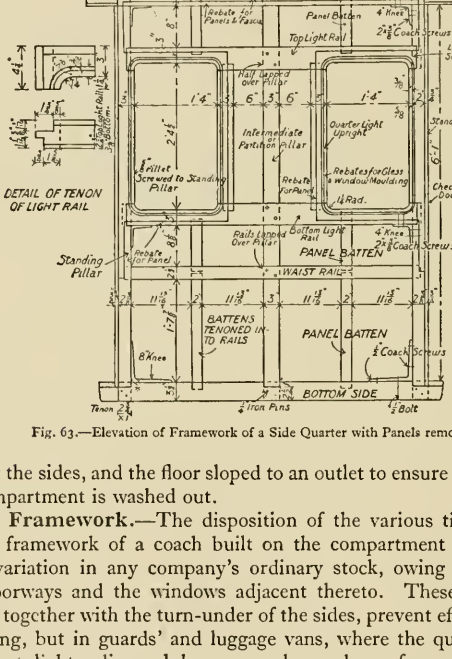


Fig. 63.—Elevation of Framework of a Side Quarter with Panels removed

formed at the sides, and the floor sloped to an outlet to ensure proper drainage when compartment is washed out.

Body Framework.—The disposition of the various timbers forming the body framework of a coach built on the compartment system permits of little variation in any company's ordinary stock, owing to the position of the doorways and the windows adjacent thereto. These doorways and windows, together with the turn-under of the sides, prevent effectual strutting and bracing, but in guards' and luggage vans, where the quarters are large and without lights, diagonal braces can be, and are frequently, used with very good results. Owing to the difficulty of not being able to strut the side framework of British rolling stock, strong and expensive timbers are required, whereas in the American type of car, constructed with straight sides, and free from doorways, strutting and bracing are generally adopted, permitting the use of cheaper timbers, which are also of comparatively small dimensions as compared with our framing.

Fig. 63 shows an example of the British practice for the framework of a coach, giving the technical names of the various members, and fig. 64, a quarter or section panelled and fasciad. It will be seen that strutting and bracing are entirely absent; hence the stability and strength of the whole depends very largely on the good fit of the joints and the additional security given by the knees. In order to strengthen the joint at the bottom of the pillars, the latter are housed into the bottomsides to the depth of 1 in., and the shoulders formed on either side of the pillar offer considerable resistance to the stresses set up in the framework.

The principal stress to which a carriage body is subjected (and which

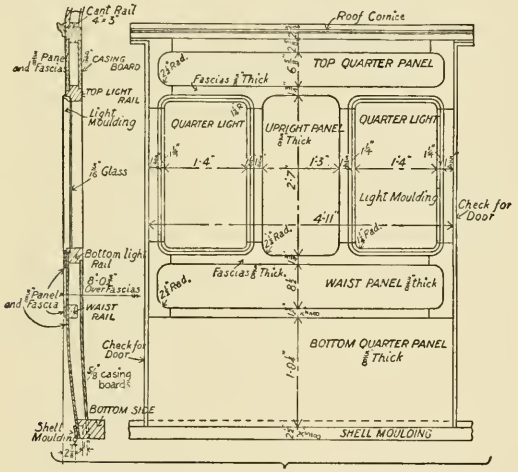


Fig. 64.—Elevation and Section of finished Side Quarter

may be considerable at times) is occasioned when a vehicle is roughly shunted and suddenly stopped, thereby causing the weight of the roof and upper framing to act obliquely upon the pillar bottom tenons, and, if movement takes place, may produce leaky quarter lights and decaying joints through the moisture working in afterwards.

Careful attention is necessary, in setting out the pillars for the framing (particularly the door pillars), to see that the grain of the timber shall run with the curvature of the pillar. Should the grain run in an outward direction, the pillar will have a tendency to warp that way, causing the doors to fit badly, and to become not only unsightly, but to rattle when travelling, a frequent cause of annoyance to passengers.

Erection.—In erecting the body—the pillars, &c., having been received in a manufactured state from the sawmill—the mortises have to be cleaned out, checks of the standing pillars cleaned up, and other necessary handwork

first performed. They are then fitted into their respective mortises with a good driving fit, and care must be taken, in fitting the door standing pillars, to ease the tenons on the check side, so as to ensure a standard-sized doorway. All pillars must be so fitted that in their free state they are truly in line from end to end, otherwise any out of line will require springing into position, thus putting great strain on the tenons when straightening the sides. The knee holes are then marked, " draw " being allowed to ensure the shoulders of the tenons bedding on bottomsides. The pillars are now taken down and removed to the bench, where the light and waist rails are fitted to them and the panel battens to the rails. The positions of holes are then marked from the knees, and the whole disconnected. The various parts of joints and knees are then painted, and the quarters framed together. When all the quarters have reached this stage, they are taken separately and placed upon trestles, where the joints are cramped together and secured by wood screws or dowels. The joints are then cleaned off and rebates routered to required depth, and the waist and upright panels fitted and secured by $1\frac{1}{4}$-in. panel pins. At the same time that the side framing of the coach is being constructed the end framing is also formed, the uprights and rails for which are generally of 3-in.-by-2-in. oak, with the exception of one toprail (in alignment with cant rail), which is 4 in. by 2 in. The uprights are secured to end bars by tenons 1 in. thick, and similarly housed into end bars as described for the side pillars; the cross rails are half-lapped on to the uprights, and the whole secured by screws. When the uprights and rails have been put together, this portion is placed in position on the end bar, and a staff nailed to each upright to keep it in position whilst the extreme ends of staff are cut to give exact distance apart for bottom of corner pillars. It is then taken down, the corner pillars fitted and secured to rails, and tested by gauge to give exact width of coach. The arch rail is formed in three pieces, of pitch pine, the centre portion being half-lapped on to uprights and secured by screws, and the end portions have one end resting on corner pillar and the other half-lapped and screwed to the upright. The corner pieces are also secured by a $\frac{1}{2}$-in. bolt, which passes through toprail and corner-pillar knee. The wood arch rail is strengthened by a ($1\frac{3}{4}$-in.-by-$\frac{1}{2}$-in. section) roof iron, which is screwed thereto, and the feet are bolted to the cant rails. The end should be tested for squareness by measuring with a staff diagonally from corner-pillar tenon to junction of toprail with opposite corner pillar; and, if correct, all joints are levelled off, and panels fitted and secured by $1\frac{1}{4}$-in. pins, the joints of panels being afterwards covered by $1\frac{3}{4}$-in.-by-$\frac{3}{8}$-in. mouldings and fascias to the form and dimensions shown on the general drawings.

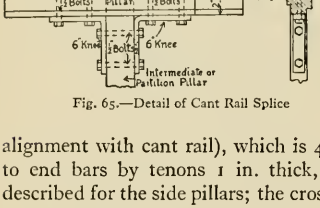


Fig. 65.—Detail of Cant Rail Splice

In the case of long bogie vehicles the cant rails are frequently spliced,

and fig. 65 shows one method of doing this. As will be seen, the ends of the splice are square, to facilitate driving the separate portions of the cant rail on to the pillars. The centre of the splice is intersected by the tenon of a pillar, and this tenon must draw the two parts of the cant rail tightly together, the joint being further secured by knees and bolts as shown.

Panelling.—When all the " quarters " have been cleaned off, the usual practice is to place the ends of the coach, with end quarters attached, into position; then the remaining quarters are put up, and the cant rails driven on. The sides are now cramped down and the knees tightened up, and two $\frac{1}{4}$-in.-diameter iron pins or hardwood dowels driven through cant rails and bottomsides into each pillar tenon. The sides are next straightened, which is done by cramping and cross strutting where necessary; and if any uneven joints are found, they are cleaned off, and the framing tested in every way with a straightedge. The bottom and top panels are next fitted and secured by $1\frac{1}{4}$ in. pins, being afterwards cleaned up, and the necessary fascias and mouldings attached. The panels for coaches intended to be painted are generally of mahogany $\frac{3}{8}$ in. thick; but, owing to exposure to all kinds of weather, they have a great tendency to split, and in order to prevent this as much as possible it is usual to back them with a coarse canvas well soaked in glue, the latter being thoroughly worked into the grain of the timber.

In addition to securing the panels to the pillars by pins, triangular wood fillets about $2\frac{1}{2}$ in. by $1\frac{1}{4}$ in. by $1\frac{1}{4}$ in. are glued into the angle formed between the framework and panel. These have a tendency to prevent splitting of the latter, owing to their grain running in a contrary direction to that of the panel; and further, some companies, with this idea, cover practically all the unsupported portion of the panel inside with small pieces of wood glued thereto. Teak panels are sometimes used for British stock where it is intended to varnish the exterior of the body, and they are also largely used for stock constructed for very hot climates. These panels are much more durable than those of mahogany, no doubt due to the large amount of oil which teak contains. Its oily nature, however, prevents glue adhering to it for any length of time, and for this reason the canvassing and blocking performed on mahogany panels are frequently omitted.

In consequence of the heavy expense entailed by the renewal of split wooden panels, nearly all companies are experimenting with various metals for this purpose (more particularly for the large bottom quarter panels), the principal kinds being generally of galvanized iron or steel.

Roof Support.—The method of supporting the roofs of carriage bodies is governed chiefly by the interior finishing of the compartments. Fig. 66 shows an arrangement where a double roof is adopted, the roof support in this case being an edge iron $1\frac{3}{4}$-in.-by-$\frac{1}{2}$-in. section with T-shaped feet, these being secured to cant rail by $\frac{1}{2}$-in. bolts or coach screws. In order to provide a fastening for the roof boards, pitch-pine packings $1\frac{5}{16}$ in. by $1\frac{3}{4}$ in. are secured to the irons by $\frac{3}{8}$-in. bolts, these packings projecting above and below the irons to allow for any cleaning off necessary in order to obtain a level roof. Narrow boards, specially machined 2 in. by $\frac{7}{8}$ in., are manu-

factured to suit the sharp curve of the roof at sides, and the intermediate roof boards are $6\frac{1}{2}$ in. by $\frac{7}{8}$ in., all being tongued and grooved. For the inside roof $\frac{3}{16}$-in. plywood is used, which in an ordinary compartment is arranged in four panels. These panels are secured to packings which are screwed to the outer roof boards. In third-class compartments the panels are butt-jointed and secured with $1\frac{1}{4}$-in. panel pins to roof packings, the joints being carefully filled with white lead. In the first- and second-class compartments the joints do not require "leading", as they are covered by fascias. Some companies use papier mâché or millboard panels about $\frac{1}{4}$ in. thickness for inside roofing, and this is afterwards covered with figured Lincrusta pasted on. Recently, steel panels of about No. 22 S.W.G. have been used for this purpose, being painted and lined after fixing, also "Salamander" or other fireproof (asbestos) panels.

Another method, largely adopted for third-class compartments with

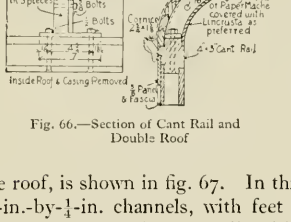


Fig. 66.—Section of Cant Rail and Double Roof

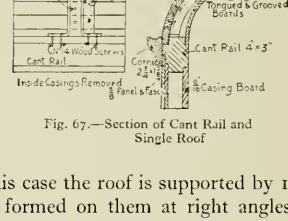


Fig. 67.—Section of Cant Rail and Single Roof

single roof, is shown in fig. 67. In this case the roof is supported by $1\frac{3}{4}$-in.-by-1-in.-by-$\frac{1}{4}$-in. channels, with feet formed on them at right angles, and secured by these to the cant rails with screws. In the channel is placed an ash fillet, which is afterwards covered with a $1\frac{3}{4}$-in.-by-$\frac{3}{8}$-in. moulding. The narrow roof boards are secured by screws put in from the inside of the channels; but the wide boards have one screw which passes up from the inside of the channel, and another which is put in from the top of the board, and enters into the ash fillet, thus securing the latter and the boards in an effective manner. The sides of the roof, inside the compartment, may be finished off as shown in fig. 67, or by a heavy moulding fixed into the angle formed between outer roof boards and cant rail.

It will now be well to briefly describe some of the leading types of bodies used on English railways.

56-ft. Corridor Composite Carriage.—Fig. 68 shows a 56-ft. corridor composite carriage with two compartments of first, second, and third class, and also one brake and van compartment and two lavatories. The first-class compartments are finished in polished wainscot oak and trimmed with figured moquette, and the second-class woodwork is of mahogany and the trimming of plush. The third class have mahogany doors and photo fascias and deal casings painted, grained oak, and varnished, and the upholstering is of figured rep. The corridor throughout is finished with mahogany fascias,

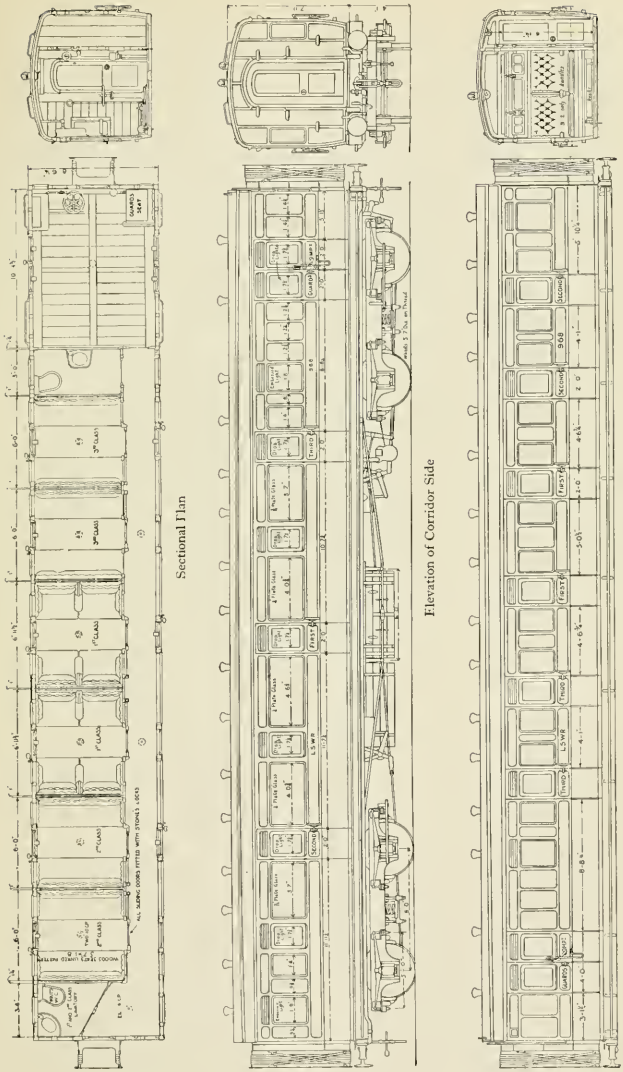


Fig. 68.—56-ft. Composite Carriage

having $\frac{3}{16}$-in. plywood panels above the waist and $\frac{3}{8}$-in. mahogany panels below, the whole being varnished. The arrangement of the corridor sliding doors is illustrated and described in the next chapter, dealing with " Finishing ", as are also the fittings of the outside doors, including the new dust screens to the drop windows. The bottomsides are cut away at each outside door to give adequate foot space on the top stepboard when passengers are alighting.

The fittings of the lavatories are of Messrs. Doulton's manufacture, and the water pipes are so arranged that in frosty weather the water may be entirely drained from the tanks and fittings, thereby obviating any possibility of burst pipes.

The vehicle is equipped with electric-bell pushes, passenger communication in connection with the vacuum brake, and steam heating, the latter being so arranged that the passengers may control the heat in the compartments.

Stone's system of electric lighting is used throughout, and " half lights " may be switched on by the guard during the journey for passing through tunnels in the daytime. The fittings are as follows:

One 24-volt, C.R.-size dynamo and accumulators containing 24 nine-plate Tudor cells.

Three 24-volt, 12-candle-power metallic filament lamps in fitting, to each first-class compartment.

Two 24-volt, 16-candle-power metallic filament lamps in fitting, to each second- and third-class compartment.

One 24-volt, 8-candle-power metallic filament lamp in fitting, to each lavatory.

Three 24-volt, 8-candle-power filament lamps in fitting, in corridor.

Two 24-volt, 16-candle-power filament lamps in fitting, in guard's compartment.

One main-lighting switch, one tunnel switch, and one magnetic switch, in guard's compartment.

An alternative arrangement of lamps in the first-class compartments is to fix two on each partition with switches just above the seat back and one lamp in centre of roof. This gives a better light for reading, and enables a passenger to switch them off if he so desires.

" Holophane " globes are often used to increase distribution of light, but to retain efficiency it is essential they must be kept clean.

The gangways are of the standard type, and are fully illustrated in fig. 47, p. 148. The underframe is of steel, to the design shown on plate IV, A, p. 102, and the bogies are similar to those illustrated in fig. 9, pp. 108–9.

56-ft. Dining Car.—Fig. 69 is an illustration of a 56-ft. combined dining and kitchen saloon, having one first-class compartment to seat eleven, and one second- and third-class compartment to seat seventeen. The pantry and kitchen are situated between these passenger compartments, and this arrangement is of considerable advantage in facilitating speedy serving.

The first-class compartment is finished with wainscot oak (or figured walnut) fascias and satinwood panels, the seats being trimmed with figured

Fig. 69.—Combined Dining and Kitchen Saloon

moquette. The second- and third-class compartments are finished with polished mahogany and plywood panels, with figured plush trimmings, and all seats are of the tip-up pattern. In order to give additional air space, these cars are constructed with clerestory roofs, in the sides of which windows and ventilators are fitted alternately. Some companies construct this " deck " part of the roof with members framed together; but in the illustration shown, the sides are made of well-seasoned pitch-pine planks, $10\frac{3}{4}$ in. by $1\frac{1}{4}$ in., running the full length of the car, the necessary openings for ventilators, &c., being merely cut therein where required. $\frac{5}{16}$-in. down-bolts are placed at frequent intervals to prevent splitting.

The side drop-windows are so arranged that, when partially down, the opening is covered with very fine copper-wire gauze to prevent ingress of grit when travelling, and the orifices of all ventilators, when open, are similarly covered. The corridor framing is of teak, with $\frac{5}{16}$-in. plywood panels above the waist, and $\frac{3}{8}$-in. mahogany panels below, the whole being varnished.

These cars are electrically lighted, steam heated, fitted with passenger communication and electric bells, and in addition are equipped with two electrically-driven fans to maintain an equable temperature in hot weather.

The cooking range is of Slater's latest pattern, and has capacity for cooking about sixty luncheons or dinners at one sitting. The water feed-tank, with a capacity of over 80 gall., is situated in the roof of the pantry, and is well jacketed with felt to prevent freezing, and neatly covered in with casings. All sinks are supplied with hot and cold water, and every convenience is given for quickly and effectively carrying out the necessary kitchen and pantry work. The entrances to both kitchen and pantry are provided with Bostwick collapsible gates, the great advantage of these being that when the vehicles are not in use, and the gates shut, the air can circulate freely into the corridor, thereby assisting in keeping the kitchen and pantry better ventilated. The pantry is fitted with special electric-bell indicators, which are capable of notifying a call from any particular carriage of the train, and also with electric-light switches giving control for " half " and " full " lights throughout the car.

Some of these dining saloons have been recently constructed with large fixed windows adjacent to each dining table, and the necessary ventilation obtained by hinged lights between the top light rail and cant rail. The appearance of the car is materially improved by this arrangement, but considerable difference of opinion exists as to which is the better system so far as the comfort and convenience of passengers is concerned.

Sleeping Saloon.—A modern type of sleeping saloon built by the London and South-Western Company has seven single berths and two double berths. The vehicle is 56 ft. long over body and 9 ft. wide at the waist; and is provided with corridor, vestibule ends, and gangways, in order to give passengers or the attendant access to the refreshment car which is usually run with night trains. A distinct feature of this saloon is the provision of separate brass bedsteads in the berths, while the absence of all padding and upholstery in the sides enables the interiors to be kept clean, and the polished

INVALID COACH

[*Facing p. 166, Vol. I*

woodwork does not readily permit the accumulation of dust. The finishing of all the berths is of specially selected wainscot oak, with Hungarian-ash veneered panels, and the inside roof is of three-plywood painted white and lined with gold. Each compartment has hot and cold water supply to the wash basin, the former being conveyed by pipes from a boiler in the attendant's compartment, and the latter from supply tanks (having a capacity of 54 gall.) which are placed in the roof at the vestibule ends. The lavatory fittings are of Doulton's special manufacture, the basin tops being of St. Anne's marble, and the basins of white ware decorated with gold. Glazed tiles are fixed round and above each basin, so that all soap splashes may be easily cleaned off; and in the double berths the lid of the wash basin forms, when closed, a convenient writing-table, and when up adequately shields the beds from any water splashes. The electric-light switches are so placed that a passenger may control the lights to give "full" or "night" light as desired; and in each compartment a special reading-lamp is fitted above the head of the berth, covered with a translucent shade to give a soft light. The saloon is steam heated on the non-storage principle, and the heat may be controlled by the passenger without getting out of bed. Each compartment has two roof ventilators, and the drop light, when partly open, gives a brass gauze panel to prevent ingress of cinders, &c., when travelling. Figs. 70 and 71 illustrate this saloon.

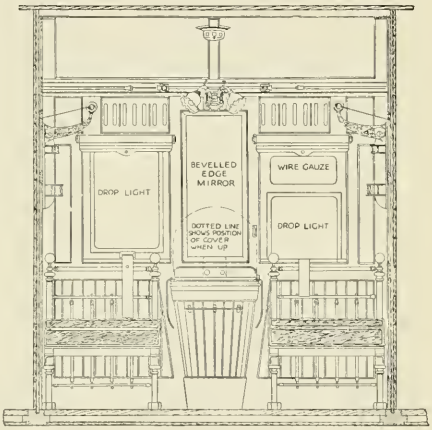


Fig. 70.—Coach Side of Double Compartment of Sleeping Saloon

Family and Invalid Saloons.—Most of the large railways provide special vehicles for the conveyance of invalids or private families; and it is very essential that a saloon of this character should be of such dimensions that it may travel safely over all lines in England, Scotland, and Wales. The body of the latest invalid saloon on the London and South-Western Railway is 46 ft. 6 in. long and 8 ft. $3\frac{3}{4}$ in. wide, and is divided into five compartments, viz. the main saloon, one first-class corridor compartment, one servants' compartment, one luggage compartment, and one lavatory. The saloon and first-class compartments are finished in polished wainscot oak with satinwood panels, and the upholstery is of handsome figured moquette with a groundwork of old-gold colour, the carpet, curtains, and blinds having

Fig 71.—Single Berth Compartment of Sleeping Saloon

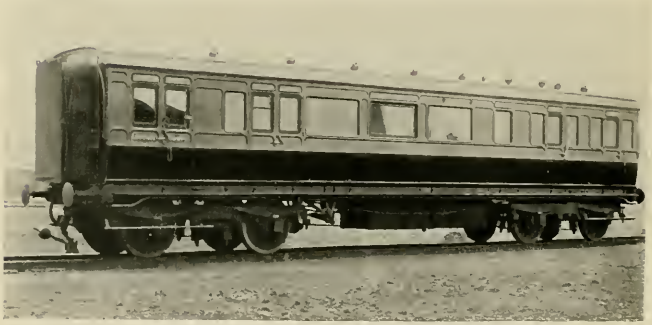


Fig. 72.—Family or Invalid Saloon, London and South-Western Railway

been chosen to harmonize. The exterior of the saloon is illustrated in fig. 72 and the interior in Plate V.

Hygienic conditions were carefully kept in mind when designing these saloons, and, as in the case of the sleeping cars just described, all superfluous padding has been eliminated, and polished woodwork takes its place.

When the saloon is used for an invalid, it is important that the journey may be made with as little personal change of position as possible; and with this end in view, the main saloon compartment is fitted with large double doors enabling a person to be carried in on a stretcher and placed on the specially designed couch without moving. This couch, when the vehicle is used as a family carriage, is apparently of the ordinary type, but by a simple mechanical contrivance it may be converted to receive a stretcher and patient; and if the latter is able to recline, the ends of the couch are so adapted as to be set at any angle necessary to give comfort in travelling. Great care has been taken with the springs, &c., in order to give smooth riding; and every modern convenience is provided to render a long journey as pleasant and comfortable as possible.

Milk Vans. — Much attention has been given recently by public authorities to the means and methods of conveying milk to the large towns from considerable distances in the country, and the bodies of milk vans must be specially designed and built in order to keep the milk sweet and clean in transit.

Many of the old type of milk vans had the side louvres at the top, but in actual practice it has been found far better that these should be situated at the bottom, thereby giving a current of air directly around the cans, while the dust is less likely to fall on the lids in transit. To prevent the dirt as far as possible from getting in, all air spaces are covered with the finest wire gauze; and not only is the inner roof insulated with felt and inner casings, but between this and the outer roof is an air cavity extending the whole length of the van, in order to give a constant circulation of cool air when travelling. Air spaces are provided throughout the side framing; and the floors are specially constructed of asphalt, which enables them to be thoroughly cleaned after each journey; and as these floors slope toward the centre, all water quickly passes away through the outlets provided in the centre drain.

The interiors are painted with enamel white, and the exteriors painted with a light colour, so as not to absorb the heat in summer.

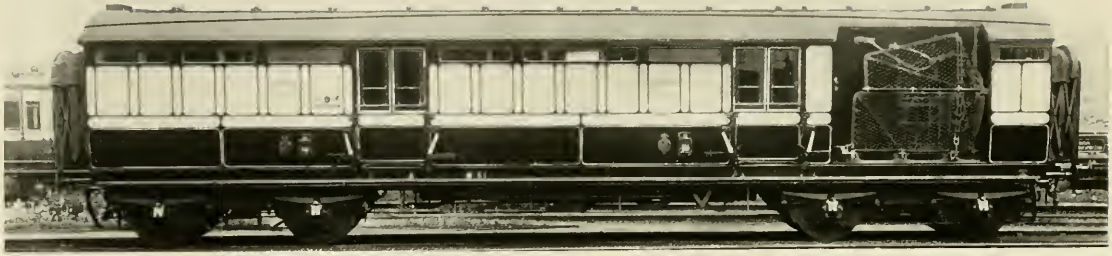
These bodies are attached to the underframes shown on Plate III, p. 100.

Travelling Post Offices.—All the principal railway companies build and maintain for the General Post Office a number of letter and parcel sorting vans, for use on the day and night mail trains, and the interiors of these vehicles are of necessity excellent examples of the " maximum of accommodation in the minimum of space ". These vehicles usually run in pairs or sets, consisting of one combined letter and newspaper carriage, coupled with side gangways (about 1 ft. 9 in. out of centre) to one or two parcel

sorting vans, according to the route travelled. In general, the interior arrangement of the combined letter and newspaper office is as follows: On the " offside " of the vehicle, at the left-hand end, is (1) a lockup registered letter set; (2) two or three ordinary letter sets; (3) one newspaper set; (4) a doorway with hinged flap inside; (5) another newspaper set; (6) two more ordinary letter sets; (7) a sliding door with flap inside; (8) a registered parcel desk; and (9) a lavatory compartment. The opposite or " near-side " of the vehicle has two sliding doors, and the remainder of the space occupied by a series of bag pegs, " Dockree " arms (for keeping the mouths of the bags open when filling), and, in those offices required to pick up and set down mail bags when travelling, the actuating gear for this work. If space permits, some sorting shelves are also fitted on this side. Portable peg rails are provided for use over the sliding doors when the latter are closed. Both ends of the vehicle are fitted with flexible gangways and sliding doors thereto. Plate VI gives an excellent view of the interior of one of the most modern mail vans, showing exactly how the various " sets " are subdivided by partitions to facilitate sorting. Plate VII shows (*a*) the elevation of the near-side, with the picking-up net folded and the arms closed, and (*b*) the net extended to receive the pouches containing the mail bags, also the arms with pouches attached pushed outwards ready for dispatch, as it must be borne in mind that the double operation of picking up and setting down when travelling is performed simultaneously. Both sides of the vehicle are provided with apertures for the late posting of letters with an extra halfpenny stamp. It will be seen from the illustration of the interior that all projecting parts are carefully padded to prevent injury to the men when working. When designing these vans, the lighting and ventilating always receive special care. Draughts have to be particularly guarded against, and thick baize curtains are provided wherever there is any likelihood of an ingress of cold air. As it would be undesirable for the steam heating pipes to be adjacent to the floor, owing to the proximity of parcels possibly containing perishable goods, it is usual for them to be carried overhead, suspended from the roof by brackets, but, of course, quite clear of the men's heads. Recently many improvements have been introduced into these vehicles, and everything possible is done to make them healthy and comfortable for the men of the Post Office staff, who have to spend so many hours therein.

INTERIOR OF TRAVELLING POST OFFICE (London and North-Western Railway)

TRAVELLING POST OFFICE (London and North-Western Railway)—Showing Nets and Arms extended for picking up



THE SAME—Showing Nets closed

[*Facing p. 170, Vol. I*

CHAPTER VIII

Finishing, Trimming, Ventilating, Polishing, Painting, and Steam Heating

The work of the finishing department of a railway or contract shop includes generally the whole of the decorative woodwork, interior doors, and windows; the fitting and making of all woodwork in connection with the seats and backs, and the making of the frames, &c., to carry the lavatory fittings. Since the introduction of passenger communication in connection with the brakes (as described in the next chapter), it is usual for the coach-finishers to fix up this apparatus. It will be seen by the items enumerated that this part of carriage-building is practically always under observation, and the interior appearance of a carriage depends largely upon the selection of the timbers and good workmanship in this branch, and also on a judicious choice of suitable upholstering material to harmonize with the woodwork. The interior finishing varies somewhat considerably on British railways, some companies adhering to a standard practically throughout their stock, and others making a special feature of their chief main-line trains, giving them luxurious finishing and spending correspondingly less on their ordinary carriages. The latter remarks apply principally to competitive systems; but it is probable, now that working agreements have become general, more uniformity will exist in the comforts afforded to all passengers, in place of giving exceptional accommodation to the few; although, of course, long-distance trains will always have some preference. It will therefore be more representative of British modern practice if the writer illustrates and describes a medium style of finishing as adopted for the first-, second-, and third-class compartments of a leading English line, than to give particulars of special trains, royal saloons, and Pullman cars, &c., which, although they are examples of the finest workmanship and design, are due to special expenditure, and do not represent average practice. The woods most generally used for interior finishing now are walnut, mahogany, figured oak, satinwood, sycamore, Hungarian ash, maple, and birch plywood.

First-class Compartment (fig. 73).—In this illustration are shown longitudinal and cross sections of a first-class corridor compartment, the finishing fascias in this case being of walnut and the panels of mahogany or pine, veneered with satinwood, the whole being polished in accordance with the particulars given later in this chapter. The fascias are $\frac{3}{8}$ in. thickness when finished, excepting those for the photographs, which are $\frac{3}{4}$ in., the edges in all cases having an ovolo shape and being painted with liquid gold. Some companies use "Bolection" mouldings extensively in their first-class finishing; and although these give a more pleasing appearance, and act somewhat as a relief to the plainness, they form a resting-place for dust, and the compartments cannot be kept clean so readily. The photo-

graph fascias are marked out by hand to templates, and after machining are then framed together and cleaned up by the finisher, ready to receive the

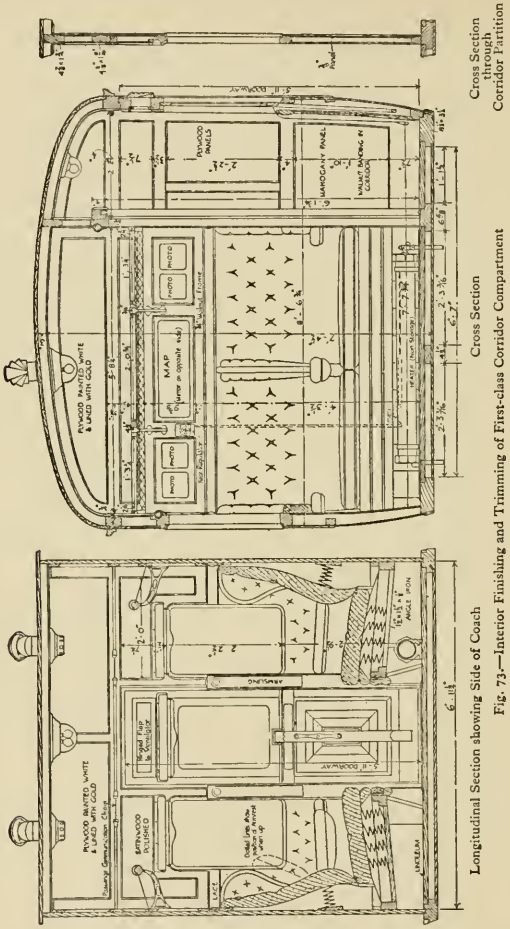


Fig. 73.—Interior Finishing and Trimming of First-class Corridor Compartment

polish. When polished, the frames have the glass, photographs, maps, or mirrors, and backs, placed in by girl labour; these girls in many shops also satisfactorily carrying out the bulk of the polishing. The " well " to receive the seat springs (in wire frame) is made up of front and back seat rails and

ends framed together, having $\frac{3}{4}$-in. bottom casings, and the whole is carried on angle irons secured to the sides of the coach. The back (seat) framework, consisting of the centre and end banjoes and top and bottom trimming rails and spring board, is made by the finisher, after which it passes to the trimmer, who fixes the springs and attaches the upholstered back. It has been

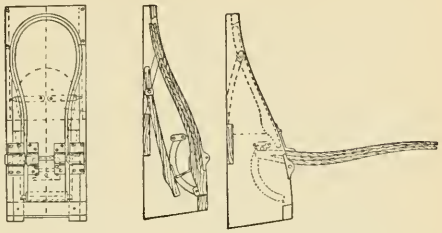


Fig. 74.—Laycock's Patent Arm Rest Fittings

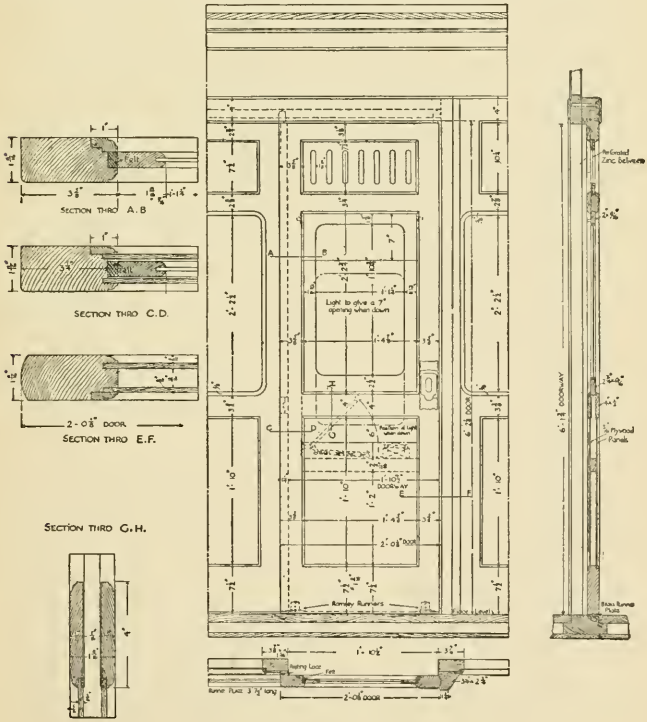


Fig. 75.—Sliding Door for Corridor Coach

found to be better, wherever possible, to make frames which can be upholstered on the trimmer's bench, in preference to doing the work inside the compartment, and in this way the parts can be taken to the coach all ready for fixing.

In fig. 73 it will be seen that the elbow can be hinged up until it touches the head rest, thereby allowing an additional passenger to sit down if the

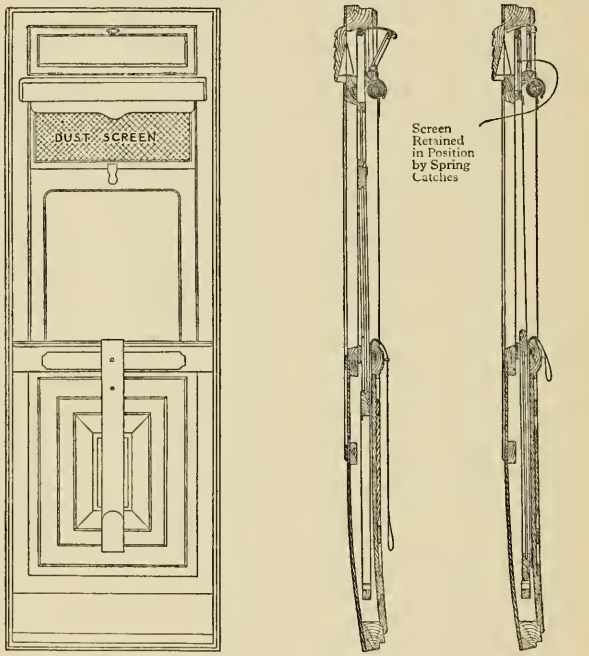

DUST SCREEN
Screen Retained in Position by Spring Catches
A
Interior view of Door, with Screen in position
B
Section showing Screen in position
C
Section showing Windows Down and Screen not in use

Fig. 76.—Carriage Door fitted with Dust Screen

train is crowded; and, with this end in view, some companies have adopted a special lift-up arm rest, which is so arranged (see fig. 74) that it gives a "flush" back both when up and down. With this device there is no unsightly cavity left when the elbow is in use.

The corridor sliding door, of which a detail is shown in fig. 75, may be taken as typical of similar doors on all lines. The stiles and rails, having been machined approximately to the finished sizes, are marked out for tenons, mortises, &c., and, after a trial fitting together, are taken apart for gluing,

and then cramped up and secured with wedges. Care must be taken that the door is square and out of winding, after which the panels, mouldings, &c., may be fitted, and the whole cleaned off and cut to exact height and width. The lock stile is shaped to suit the stop pillar, and the fittings (locks, &c.) carefully fitted to their places. The whole should be finally cleaned up, ready to be dealt with by the polisher.

The outside doors are framed together, hung, and fitted by the body-maker, but all the inside mouldings and panels, drop lights, and ventilation slides are made and fitted by the finisher. It is now more general for the insides of the doors of all classes of compartments to be free from padding, the bottom panel having frequently a carved centre. An illustration of an outside door is given in fig. 76, showing the usual framework and fittings, and in addition at the top an improved dust screen, which has met with considerable approval from the travelling public. A description of this screen will be found on p. 180.

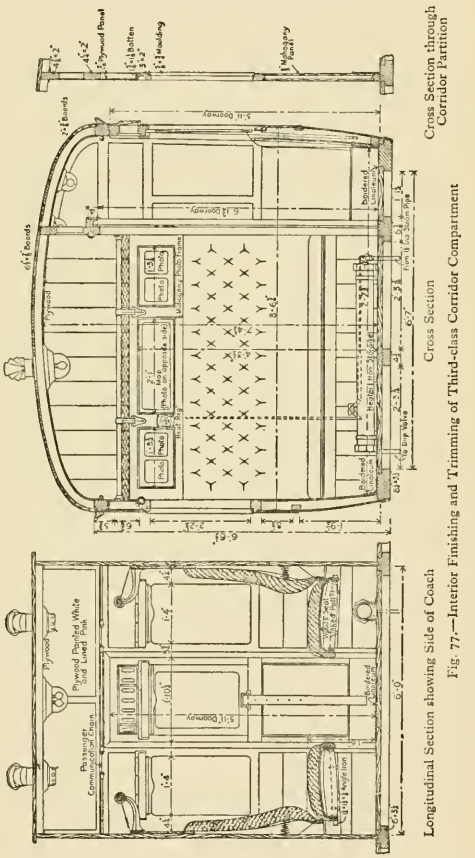


Fig. 77.—Interior Finishing and Trimming of Third-class Corridor Compartment

Owing to the large number of cases of injury to passengers' fingers when the doors are being closed at stations, some companies put protective mouldings on the standing pillars of their carriages, so that it is difficult accidentally to place the hand in such a position as to get the fingers trapped. These mouldings are more generally fitted on suburban trains only, on account of the frequent opening and shutting of the doors.

The plywood roof panels are fitted by the finisher, and when these have received their coats of paint, the fascias and roof fittings are fixed in position.

Second- and Third-class Compartments.—As regards the finishing of second-class compartments, it may be said that, with the exception that the fascia work is of mahogany and the panels of plywood, the style of finish is very similar to that just described for the first class. The whole of the woodwork, however, is finished with varnish, and the seat frame is of woven wire (Wood's), and has a plain fixed cushion thereon. It is claimed that these seats save a considerable amount of horsehair and are generally more hygienic.

In fig. 77 two views are given of a third-class compartment. The doors and photograph fascias are made of mahogany and are varnished, the remainder being painted and grained " oak ". Some companies (particularly those which do not run second-class carriages) make the thirds a little more elaborate, and by the use of papier mâché or plywood panels painted and lined, give to the thirds a rather better appearance. The seat is of the same pattern as that just described in connection with the second class. The painting will be described in the part dealing with that work.

Frameless Windows; Lavatory Fittings.—Frameless window glass is sometimes used on the Continent for railway carriages, and at least one leading English railway — the North-Eastern — has extensively fitted its carriages with these lights. The chief advantage of them lies in the economy effected by the absence of a frame, and obviously the saving of repairs, for owing to the rain getting into the grooves and joints of wood-framed lights they have to be renewed fairly often. These windows are usually used in connection with the " lazy-tongs " window lift (Laycock's), shown in fig. 78; and the only disadvantage is that there is no fence plate, and consequently rain may percolate through the joint of the brass plates, and it is therefore necessary to fit zinc trays inside the casings to prevent the wet, which might accumulate, from rotting the bottom sides and framing. Probably this difficulty may be overcome in course of time. These lights have also been fitted to dining and other saloons, with a suitable lever arrangement for raising and lowering such large windows.

It hardly comes within the scope of this article specially to describe and illustrate the varied types of railway-carriage lavatory fittings, but it may be mentioned that modern practice is very much in favour of whiteware for these in preference to metal. The reason for this is that although the metal fittings look very nice when new, they require more attention to keep them clean than those of earthenware; and now that lavatory accommodation is extensively provided on all the long-distance lines, the care of the lavatories entails a heavy expense upon the companies. The interior finishing of the lavatory compartments has received a good deal of attention in recent years; and with a view to giving the most hygienic conditions possible, the compartments are made so that they can be easily wiped or washed down from time to time. Some companies use tiles or " Decolite " for the floors, and " Decorite " or " Muralite " for the sides, whilst others cover the partitions

with a special covering known as " Emdeca ", or alternatively with enamelled plates. Plain pine boards (varnished) are also used for the sides, and the interiors of many are painted throughout with enamel white and lined with liquid gold.

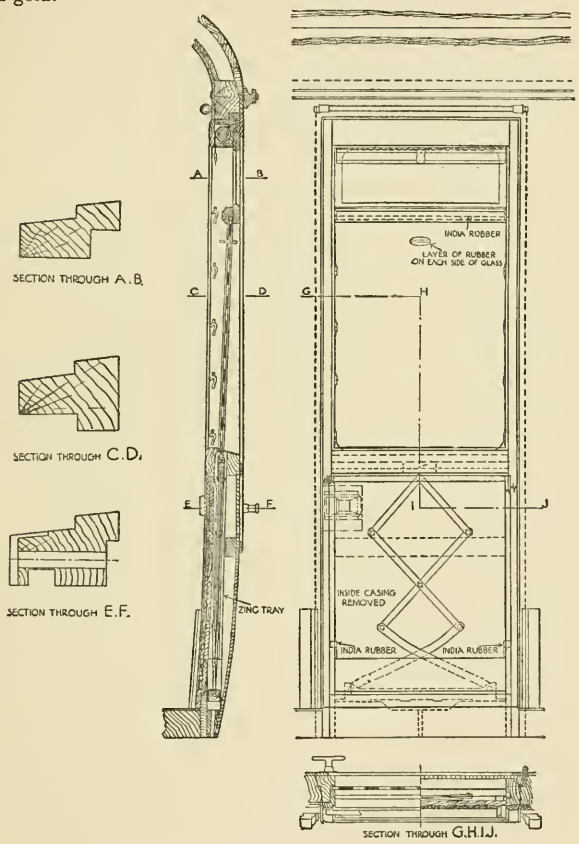


Fig. 78.—Door fitted with Frameless Door Light

To enable passengers to have a hot-water supply in the lavatories as well as cold, some companies have experimented with arrangements for heating the water by means of pipes connected to the steam-heating apparatus, but at present very few coaches are so fitted. A device for the same purpose, by utilizing the waste heat from the gas lamps, has also been tried. These

arrangements are as yet, however, more or less in the experimental stage, and cannot therefore be said to be modern practice.

Trimming.—Many of the remarks referring to finishing made at the beginning of this chapter also apply to trimming, and these two branches of carriage-building are so closely allied that it is impossible to write respecting one without in some measure encroaching on the other. The work of the trimming department includes the making of all seats and backs, blinds, glass-straps, paddings of horse boxes, covering roofs, leather-work for gangways, halters and ropes for horse boxes, insulating of all lavatory tanks and steam pipes, and a host of miscellaneous jobs, such as the making of ticket and cash bags and dispatch cases, &c., many of the latter being made from the " falling " leather when manufacturing the larger items enumerated.

The upholstering of the carriages forms a very heavy item of expenditure to all companies, owing to the high cost of the materials used, particularly horse hair; and it is far more economical to adopt the best materials procurable than to put in inferior qualities. The heavy wear and tear to which the cushions and backs are subjected in traffic, and the constant brushing and cleaning required, render the hardest wearing material absolutely necessary.

For ordinary stock, the materials chosen for upholstering should be of somewhat sombre colours and tints, as otherwise they quickly show the dirt and look shabby although scarcely worn. Another very important point is that some materials will stand the sun and the exposure to the atmosphere far better than others, even if the latter are of the same quality and price; and it is general practice for the large railway companies to make trials and tests before extensively adopting a particular pattern. Special vehicles, which are seldom used, and can therefore be constantly under care in shops, are often trimmed in expensive figured tapestries and silks of light colour, and, with the woodwork to match, have a very handsome appearance. For first-class compartments the average practice is to upholster with any one of the following materials: figured moquette (cut and uncut), dark-blue and dark-green cloth, morocco leather or buffalo hides. For second- and third-class compartments " plush " or " reps " are generally adopted; but in some districts horse-hair seating is used and is preferable, as the smooth surface does not readily absorb the dirt, and for smoking compartments the open character of the material assists in permitting the smoke to get away.

Upholstery in First-class Compartment.—The description given below refers to the first-class corridor compartment shown in fig. 73, p. 172, and, in general, will cover average trimming practice for ordinary first-class passenger compartments.

The material for the various parts is first cut out to template by men constantly employed thereat, and then passed to the lining room, where, by girl labour, it is machined, or hand-stitched where required, and then handed to the trimmer. The latter does all the stuffing and the buttoning required, and would deal with the back frame (described on p. 173) by fastening on the spiral springs to the springboard and covering them with a strip of linen, afterwards fixing on the back squabs, ready for placing in the compartment.

The hinged elbow- and head-rest are also trimmed and stuffed on the bench, ready to be fixed in position to make the division in the seat and back. The pads adjacent to the side quarter lights are made up and finished off with pasting and seaming laces. The side elbow-rests and quarter boards below them, having been similarly prepared, are screwed in position to the side of the coach. The door pillars are covered with material, stuffed, and a welting formed also of the same material so as to prevent draught at the joint of the door, the whole being finished with laces. The arm slings are made of 3-in.-broad lace, backed by buffalo leather, and when stuffed are fixed to the pillars by brass fasteners. As a finish to the back, a rail stuffed and covered with lace is fitted directly under the photograph fascias, and above the latter is a net of cord, forming a receptacle for light luggage. The resilience of the seat is given by a Peter's patent " clip " framed spring, carried in a well, and over which a double thickness of linen is secured. A front seat rail is upholstered and finished with laces and afterwards attached to the front of the well. A small stuffed roll of canvas and material is fixed above the rail just mentioned, to carry the front of the loose cushions. The latter, which consist of material piped with seaming lace and lined with calico, should be very carefully stuffed and buttoned so as to give a comfortable seat. The blinds are of tapestry, bound on the bottom edge with leather, and when attached to the spring roller are placed in position in a recess of the top light rail, and covered over with a metal cover painted to suit the colour of timber and lined with gold. The floor of the compartment is covered with linoleum, and a Tournay—or, if a smoking compartment, a horse-hair—rug is provided between the seats.

The glass-straps are made of 3-in. lace lined with canvas and backed with buffalo leather. Some companies use small white lace antimacassars pinned on the seat backs, and from the point of view of cleanliness these are very desirable, as they can be detached and cleaned as required. Curtains are very seldom used now for ordinary compartments, and if fitted to saloon windows are generally of damask or tapestry to match the upholstery. Inlaid linoleum is now very largely used for the floors of saloons, and Axminster or Brussels carpets only for first-class work.

Second- and Third-class Compartments.—The second- and third-class corridor compartments are dealt with by the trimmer in a similar manner to that described for the first-class, with the following exceptions. The back seat frames are a fixture in the body, and the door pillars are covered with varnished wood fascias instead of pads. These fascias secure the door welting to prevent draught. The woven-wire seats, of Wood's linked pattern, are upholstered at the bench, and finished to give a plain buttonless seat, which is far preferable for third-class compartments, as there are no recesses to harbour dirt. The floors of corridor seconds are treated similarly to those of the first-class, but ordinary seconds may have coir mats, without linoleum. The third-class floors have bordered linoleum 30 in. wide across the compartment. The glass-straps of the second class are usually of buffalo leather stitched with a design, and the third class of plain leather.

Although it is not possible to give a definite rule as to the length of time before the upholstery has to be renewed, it may be stated that for main-line coaches the first-class compartments require complete retrimming about every eight years, seconds about every six years, and thirds about every four years. The latter figure would also apply to *all* compartments of trains constantly running in crowded suburban services.

Ventilation.—The chief ventilation of a railway-carriage compartment consists of the drop windows and roof ventilators, the latter being generally of an exhaust type, coming into action when the train is travelling. In addition (for use when it is not desirable to open the windows) there are usually provided sliding " hit and miss " wood shutters or hinged flaps immediately above the drop lights, and the openings of these are partially covered on the outside of the vehicle by what are technically known as " bonnets ". Some companies have further a small hinged light above each side quarter light; but as the additional window is not necessary for purposes of light, it may be objected that the extra area of glass will in the summer-time, with the sun shining through it, somewhat neutralize the effects of the additional entrance for air. The main objections to the ordinary windows when opened are the draught and dirt to which the passengers are subjected, particularly those who may be facing the direction in which the train is travelling; and to minimize this a number of carriages have recently been fitted with the device shown in fig. 76. This consists of a dust screen (which also considerably breaks up the direct draught) situated, when out of use, behind the hinged ventilating shutter. When the window is partly open, it may be placed in a moment in position, as shown in views A and B. The ordinary operation of closing the window automatically replaces the screen out of use; and it will be seen (view C) that it in no way interferes with the full space made when the window is dropped, thus enabling passengers to converse with friends on the station platforms.

In corridor compartments it is usual for the window of the sliding door to open, either partially or fully; but in general these open only about half-way (see fig. 75), and if further ventilation is required the door itself may be slid back.

Of roof ventilators there is a very large number of patterns, but the two in most general use in this country are the " Torpedo " (Laycock's) and the " Acme " (Ash's). These are both illustrated in fig. 79, and their action of exhausting air is shown by arrows on the diagram. Some companies put two ventilators in each compartment, whilst others use only one in non-smoking compartments and two in " smokers ". The inside fitting is in both cases alike, and it is found that the tray type of " hit and miss " is the best for the prevention of cinders falling in the compartment when the train is passing through tunnels. For ventilating clerestory roofs of carriages the " Torpedo " ventilators are carried on the sides of the " deck ", as the height of the vehicle precludes them from being placed at the centre. It has been found by actual tests that they are equally effective in the side position as shown in fig. 69, p. 165.

Many dining saloons are now fitted with electric fans, and these are usually driven from the lighting plant. These fans are very necessary for such cars, as it is unpleasant, whilst eating, to have the windows fully open, even if very hot, owing to the grit which blows in upon the tables. Experience has shown that the temperature of the compartments may be kept much lower by the constant circulation of air by the fans.

The kitchens of dining saloons become very hot in summer-time, owing to the large number of gas jets burning for cooking purposes; and in addition to side drop-windows (fig. 69) and " deck " ventilation (" torpedoes " and glass louvres), they are sometimes fitted in the roof with one of Stones' electric motor centrifugal fans for exhausting the hot air and smells, and this also is driven from the lighting plant.

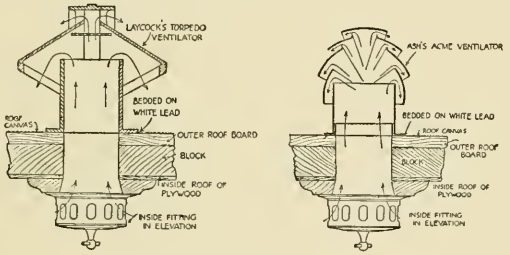


Fig. 79.—Details of Carriage Roof Ventilators

Polishing.—The article for polishing having been received, properly cleaned up, from the finishers, it is first oiled with linseed oil and filled in with whiting and turpentine (or plaster of Paris mixed with oil and polish), colour being added in mixing to suit the kind of timber and the final " tone " desired. It is then well cleaned off with coarse canvas pads and rubbed down with fine glasspaper and then polished. This first part is technically known as " setting in ", and after this stage is completed the work should be allowed to stand until it gets perfectly hard, when it is again " flatted " with fine glasspaper and " bodied " in. At this stage the article should stand for drying as long as possible, when it should again be flatted, " bodied ", and finally finished with polish and pure methylated spirit.

If the work is intended to be finally finished with varnish, the same first process is gone through, after which it should receive one or two coats of good transparent varnish.

Economic Aspects of Painting and Varnishing.—The tendency of modern practice is to use darker colours in preference to light ones; and as an instance of this the Great Western Company has recently adopted lake in place of its previous standard of cream and dark-brown, and the London and South-Western Company green, relieved with yellow and black lines. This is undoubtedly done because the darker colours do not so readily show the dirt, and further, they stand the constant cleaning (particularly if water

is used) better than lighter colours. The exterior decoration of carriages with coats of arms, &c., has been considerably curtailed in recent years, and in general the outsides of the vehicles are becoming plainer, less expenditure being placed upon them. Owing to the exposure to all kinds of weather —extreme heat and cold—it will always be necessary for the woodwork to be thoroughly well protected; but beyond this, and reasonable decoration, all further expense may be said to be superfluous.

In the following paragraphs the writer has endeavoured to give a fair average practice in the painting of standard rolling stock, and also the average process adopted for vehicles finished in the natural wood colour, i.e. teak. It may be pointed out that some companies which turn out their stock finished with varnished teak when new, do not go to the expense of maintaining them in varnish, but after a lapse of years the remaining life of the vehicles is finished out with paint. Although no hard-and-fast rule can possibly be laid down as to the number of years a vehicle will run without repainting, owing to the great variation in the cleanliness of the districts it may work in, it may be stated that a fair average for coaches is about five years, and for wagons about four years. Again, the amount of accommodation provided for the " housing " of carriage stock not required during the winter months has a marked effect upon the question of repainting, as stock left standing exposed in sidings rapidly deteriorates in many ways.

Painting of Carriage Body.—Clean off all paint, &c., protruding from the joints, and thoroughly sandpaper the surface. Then give the teak portions a coat of gold size or knotting, to be followed all over with two coats of priming and four coats of filling. The work should be stopped with hard stopping between coats and afterwards given one coat of stain, and then rubbed down with pumice stone to a perfectly smooth surface. The upper portion of coach should receive three coats of top colour, and one coat of varnish top colour; the lower part and ends to receive two coats of lead colour, one coat of brown (stopped and fine-sandpapered between the coats of lead colour), and one coat of varnish colour. The body can then be picked out with dark-brown and fine lined red, and the quarter light mouldings finished mahogany colour. The writing to be gold with a black shading line, and the whole surface given one coat of first-coating varnish and two coats of elastic finishing varnish, flatting down to take place between the coats.

Painting of Carriage Steel Underframe.—All parts to be thoroughly cleansed from rust and dirt and given one coat of anti-corrosive paint and one coat of lead colour. The faces of solebars and headstocks to receive four coats of filling (stopping to take place between the coats) and one coat of stain, and to be well rubbed down with lump pumice stone. Afterwards the work must be given one coat of lead colour, one coat of brown, one coat of varnish brown, and one coat of varnish; fine-sandpapering and stopping to take place between the coats of paint.

Painting of Compartment Interiors.—In the first- and second-class compartments the timber forming the recesses of all windows ought to

receive one coat of knotting, and then be filled in with " polish filling " and stained to match the interior woodwork. Next it should receive one coat of knotting, followed by one coat of varnish, and then be flatted down. It is finished with a coat of best transparent varnish. Before painting the third-class compartments clean off all paint, &c., from joints and fine-sandpaper the surface, then gold-size all teak parts, and give knots (if any) in deal portions a coat of knotting; after this apply two coats of priming, and between these coats all holes, &c., should be stopped and the surface fine-sandpapered. One coat of buff colour is next given, then one coat of oak-graining colour, followed by combing and graining, after which the necessary writing is done, and the whole finished with one coat of varnish. The roof receives three coats of " oil white " and one coat of " flat white ", and is then picked out and stencilled. The floor is given one coat of lead colour and one coat of brown.

Roof Painting.—The outsides of the roofs receive one coat of lead colour, and joints and screw holes are properly stopped. One good thick coat of white lead is then applied, upon which the canvas is bedded and tightly stretched, and secured at the cornices. This is followed by three coats of white paint.

Varnishing of Teak Coaches.—Carefully remove all dirt, &c., from pinholes, and give one coat of best gold size, then stop up all holes with putty coloured to match panels, and sandpaper to an even surface. Apply one coat of best hard-drying, first-coating varnish, then two more coats of varnish, the last to be rubbed in whilst wet with a flat piece of pumice stone having an even surface. After this, apply two coats of varnish, the second when dry to be flatted down with pumice powder and cloth, both being damped with water, and afterwards washed down with clean water and wiped dry with chamois leather. The ironwork of the body having been dealt with at the same time as the timber surface by receiving four coats of paint, it is given at this stage a coat of stain and grained to match the panels; and further, any light-coloured timber is stained to match surrounding surface. The writing and lettering is now done, and followed with one coat of varnish and two coats of finishing varnish, flatting down to take place between these last coats.

In some cases a coat of patent stain and filler is applied with a brush to the bare panels before the coat of gold size, and wiped off, before it becomes dry, with clean cloths or wipers. Some companies finish the outside ironwork bronze-green or black.

Before painting steel underframes of teak coaches, all parts must be thoroughly cleansed from rust and dirt and given one coat of anti-corrosive paint and one coat of lead colour. The faces of solebars and headstocks should receive four coats of filling (stopping to take place between the coats) and one coat of stain, and be well rubbed down with lump pumice stone. Afterwards give three coats of teak colour and one coat of varnish, fine-sandpapering and stopping to take place between the coats of paint. The ironwork on face of solebar is to be finished bronze-green.

Painting of Wagons and Road Vans.—If the wagon has a steel underframe, first scale and clean off all rust and dirt, and give two coats of anti-corrosive paint to all its members. Some companies adopt a process of " pickling " for their steel scantlings for wagon frames, and in this case the members are immersed in a solution of sulphuric acid and water, in the proportion of one of acid to five of water by weight, and they are kept in this solution for about half an hour. At the end of this time they are taken out, well drained, and placed in an alkaline solution of lime water for about a quarter of an hour to kill the acid, and are afterwards dipped in clean water. When the members are dry, they are painted with two coats of graphite paint. If the frame is of oak, it is given one coat of lead colour all over. All knots ought to be well " knotted ", and the outside of the body to have one coat of lead colour, followed by puttying up where required, and a further coat of lead colour. When thoroughly dry, both the body and outside of underframe should have one coat of dark-brown. The required lettering and numbering is to be done in white, and all ironwork, buffers, axleboxes, &c., to be " blacked " up. The inside of the body receives one coat of lead colour.

As regards road vans, the following coats should be given: on body—two coats lead colour, one coat solid brown, one coat varnish; on fascias—three coats solid top colour, one coat varnish colour, two coats finishing varnish, lettering as required; on wheels and under-carriage—two coats light Venetian priming, one coat oil red, one coat varnish and red, and two coats of varnish.

Steam Heating.—On nearly all railways the heating of the carriages is effected by steam from the locomotive; and although many trials were made to endeavour to accomplish this with the waste steam, it was found quite impracticable, without pressure, to obtain and maintain sufficient warmth throughout the ordinary length of a train. The present practice is for the steam from the boiler to pass through a reducing valve on the engine, bringing the pressure to about 60 lb. to the square inch, before it passes through the train. If the latter consists of from six to eight coaches with the pipes and fittings all cold, ten to fifteen minutes will usually be found sufficient to heat them right through; and if a pressure of 25 lb. is maintained on the journey, this will be adequate to keep up uniform heat in all the compartments. Two systems are in general use—one known as " storage ", and the other as " non-storage ". The former has each heater fitted with an internal tube which contains some solution, such as acetate of soda, or strong brine, which will not freeze, and absorbs the heat and gives it off again gradually. The " non-storage " system has plain heaters consisting of a tube forming a receptacle for the steam, and when the latter is shut off, the heater cools down quickly, and this system is the one now being principally adopted.

It was considered a few years ago, in consequence of the large interchange of stock on the various lines, that all companies should adopt for general practice certain uniform arrangements for the heating of their carriage stock;

and after many experiments and tests, the following regulations were agreed to by all:

1. The number of square inches of heating surface per cubic foot of compartment to be from 1·8 to 2·75.

2. That 50 lb. per square inch be the maximum steam pressure.[1]

3. That, for ordinary train traffic, no main pipe be less than $1\frac{1}{2}$ in. internal diameter.

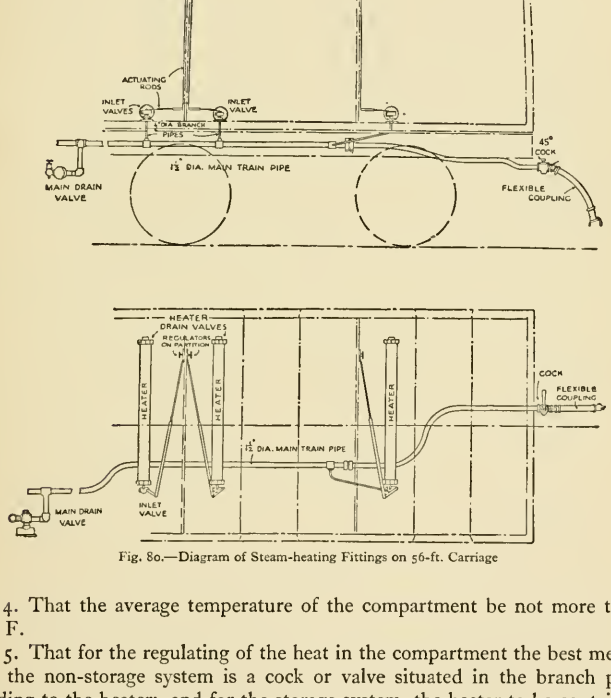


Fig. 80.—Diagram of Steam-heating Fittings on 56-ft. Carriage

4. That the average temperature of the compartment be not more than 55° F.

5. That for the regulating of the heat in the compartment the best means for the non-storage system is a cock or valve situated in the branch pipe leading to the heater; and for the storage system, the heater to be contained in a box, with an arrangement for opening and closing a lid or shutter thereon.

6. That each vehicle be so fitted as to completely drain itself.

General Arrangement of Fittings.—Fig. 80 is a diagram showing the usual arrangement of the pipes and heaters fitted to a carriage. In

[1] 60 lb. pressure on the engine, as mentioned above, will not give more than 50 lb. average pressure throughout the train.

this case the 1½-in. main steam pipe is carried through the underframe, and terminates at each end with a 45-degrees standard cock, a straight screw nipple, and a flexible coupling, the latter being of a universal design. By arrangement all companies have the heating pipes terminating 7½ to 12 in. from the centre of the vehicle, to the right-hand side, when facing the end, to facilitate coupling in interchange of traffic. From the main the steam passes through ½-in. branch pipes and the inlet valves to the heaters, the latter being so inclined that any condensation will drain off (at the opposite end to the inlet) by passing through a ½-in. pipe and a specially designed drain valve fitted to the end thereof. The main train pipe is so put in position that there is a slight fall towards the point at which the main drain valve is situated; and on very long coaches two of these valves may be used. Both the main drain valve and the small heater drain valve are of the thermostatic type, usually working by the expansion and contraction of a volatile fluid under variation of temperature. The flexible couplings are also fitted with a drain valve, but this is actuated by gravity. The controlling gear actuating the inlet valve to heaters is shown in fig. 73, p. 172; if the system is of the storage type, a similar arrangement is used to actuate the lid or shutter of the box containing the heater. The operation of closing this lid or shutter generally uncovers holes or slots in the floor, admitting cold air into the box and around the heater. With the non-storage heater it is desirable that some means be used for protecting bags, &c., from being placed on the pipe, and a very good arrangement is the hinged wire screen, as shown in the coloured model.

It may be noted that in some cases the main steam pipe is carried under one of the stepboards, or if the underframe is of wood it may be carried on the top thereof, being partly let in to the cross members where required. The main steam pipe is always insulated with some such material as felt, tightly bound thereon with coarse canvas. In those cases where it is not convenient to use heaters under the seats, the alternative arrangement of pipes at the sides of the compartment is adopted, as in the case of the dining car illustrated in fig. 69.

Special vehicles of the Pullman type, where an attendant travels with the car and can see to the apparatus, are generally equipped with a heating arrangement by hot-water circulation, and in this case each vehicle is self-contained. With a view, however, that should such vehicles be placed in an ordinary train the common connections for steam heating shall not be broken, they are equipped with a through main steam pipe; and the latter remark also applies to horse boxes, covered and open carriage trucks, luggage vans, and similar vehicles.

The foregoing description represents average practice in this country, but there are several patented systems and a large number of specialities in use. The writer feels it would be obviously unfair to enter into and describe any particular one without dealing with all, which of course is not possible, as it would form a lengthy article in itself, and is quite beyond the space at the writer's disposal.

CHAPTER IX

Continuous and Hand Brakes—Passenger Communication

The two continuous brakes in general use in this country are the "vacuum automatic" and the "Westinghouse automatic". The former may be briefly described by saying that its power is derived by creating a vacuum in the train pipe and cylinders to keep the brakes "off", and by re-admitting atmospheric pressure to apply the brakes. The latter system is practically the converse of this, inasmuch as the brakes are kept "off" by maintaining air under pressure, and they are applied by permitting this to resume its normal state. In both systems any accidental parting of the train immediately applies the brakes.

The vacuum automatic brake is in more general use in the British Isles than the air-pressure system, but the latter is almost exclusively used on the continent of Europe and in North America. A general description of the vacuum brake and its action is contained in the following paragraphs, reference being made (by letters) to the various parts on the diagram shown in fig. 81.

Description of Vacuum Brake.—This brake stops the train by the application of brake blocks to the tyres, in the same way as the ordinary hand brake. The levers, however, which apply the blocks are moved by a piston working in a cylinder, the piston deriving its power from the pressure of the atmosphere.

It is continuous, each vehicle carrying its own brake cylinder A, which is connected to a pipe B running from end to end of the train, and it is through this pipe that the action of the brake cylinders is controlled.

An ejector fixed upon the engine exhausts the air out of the continuous pipe and the cylinders. The brake is applied by the admission of air into the train pipe, and released by the withdrawal of the air through the ejector. The brake can be applied by the guard, and is instantaneous in its action, and can be regulated to a nicety for easy stops, or to control the train on an incline.

Action.—The engine having been coupled to the train, and the hose couplings connected between the tender and train and also between the coaches, and the one at the rear end of the train having been placed upon the plug, the driver admits steam to the small ejector, which soon exhausts the train pipe and cylinders to a vacuum of from 18 to 25 in.; or the large ejector may be used if the vacuum is required to be obtained more rapidly. The small ejector must be kept at work continuously to maintain the vacuum, unless a pump is used.

To apply the brake, the driver moves the handle of the combination ejector in the direction marked "ON", thus admitting air to the train pipe

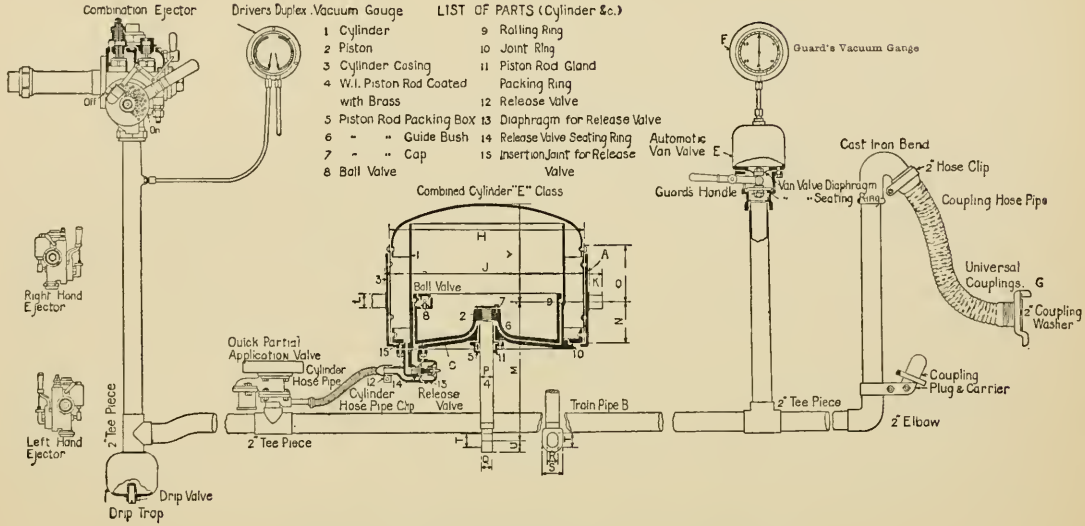


Fig. 81.—Diagram showing General Arrangement of the Vacuum Automatic Brake

B and to the bottom, C, of each cylinder, where it lifts the pistons and so pulls the blocks to the wheels. The air cannot pass to the top of the piston, as it is prevented by the rolling-ring and the ball in the valve. The power of the application is controlled by the amount of air let into the continuous pipe. To release the brake, the handle must be returned to "RUNNING POSITION", when the air let in to apply the brake will be removed through the small ejector; or it may be released more quickly by pushing the handle in the direction marked "OFF", and so admitting steam to the large ejector. The brake having been applied, the pressure of the blocks on the wheels may be increased or diminished at pleasure without reducing the full reserve power of the brake, which is always at command for an emergency stop.

Station stops should not be made by a violent application of the brake, but by a destruction of vacuum of, say, from 5 to 10 in., which should be re-created slowly as the train comes to rest, by placing the handle in "RUNNING POSITION". By having the vacuum nearly restored at the end of the stop, jerking is prevented, and the brake is released without the use of the large ejector. To apply the brake quickly, the handle must be moved to the position marked "ON", thus fully opening the air valve.

The guard can apply the brake by pressing down the handle of his valve E, thus admitting air and applying the brake throughout the train, which will be stopped even if the engine remains under full steam. When a rapid application is made by the driver, the guard's valve opens automatically, letting in air from the van, thus increasing the rapidity of application, and it closes again after the brake has been fully applied.

When it is desired to release the brake on coaches detached from an engine, the wire at either side of the vehicle must be pulled. This wire is attached to the release lever of the ball valve, and by pulling the ball off its seat, allows the air to pass to the top of the piston, destroying the vacuum, and so releasing the brake. In the latest types of cylinders, where the ball valve is within the piston, the wire actuates the release valve, and by removing it from its seat makes connection between train pipe and vacuum chamber, thus releasing brakes. While this is being done, a coupling must be left off the plug at the end of the train to allow the air to enter and destroy the vacuum.

A detailed description of each of the fittings used on the carriages is given below. The size of the cylinder and arrangement of levers used should be such that the braking power on the vehicle will be about 80 per cent of its total weight.

Combined Brake Cylinder (A).—This is the principal fitting and that shown in section on the drawing (fig. 81) is of the E-class. The piston fits freely in the cylinder and is packed with a rolling rubber ring, which, when the piston moves, rolls between it and the cylinder, making a perfect packing with practically no friction. (See fig. 82). The piston rod is coated with brass and works through a brass bush, and a packing rubber prevents air passing the rod. (See fig. 83.) This rod should be kept clean by wiping with a dry cloth, but no oil or grease must ever be used. It will be noticed

that the hole in the bottom of the piston rod is elongated; the object of this being that it allows the piston to lift about $\frac{1}{2}$ in. before it commences to actuate the brake levers, allowing the ring to move out of its recess and become compressed, effectually making a tight joint. The advantages claimed for this design are as follows. The retention of the vacuum above the piston is not dependent upon the tightness of the ball valve, for immediately the brake is applied the piston moves, and the ball valve is cut out; therefore, with this arrangement, external influences, or grit on the valve seating, do not in any way affect the efficiency of the cylinder by causing loss of vacuum in the chamber. The ball valve being placed high in the piston, rust and dirt cannot fall into it; and in general the retention of the maximum vacuum above piston makes this cylinder particularly suitable for trains working on long and steep grades. The following table shows the dimensions of these cylinders as indicated in fig. 81:

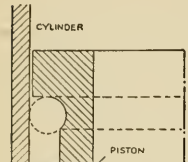


Fig. 82.—Cylinder Rolling Ring under Compression, Vacuum Brake

Dimensions of Combined Cylinders, "E-class"

Diameter.	12 Inches.	15 Inches.	18 Inches.
	Ft. In.	Ft. In.	Ft. In.
H.	1 $5\frac{7}{8}$	1 $8\frac{1}{4}$	1 $11\frac{1}{4}$
J.	1 $6\frac{5}{16}$	1 $9\frac{1}{4}$	2 $0\frac{1}{4}$
K.	0 $1\frac{5}{8}$	0 $1\frac{5}{8}$	0 $1\frac{5}{8}$
L.	0 $1\frac{1}{4}$	0 $1\frac{1}{2}$	0 $1\frac{1}{2}$
M.	0 $12\frac{3}{16}$	1 $4\frac{9}{16}$	1 $4\frac{9}{16}$
N.	0 $4\frac{1}{4}$	0 5	0 5
O.	0 $3\frac{1}{4}$	0 $6\frac{1}{2}$	0 $6\frac{1}{2}$
P.	0 1	0 $1\frac{1}{2}$	0 $1\frac{1}{2}$
Q.	0 $\frac{7}{8}$	0 $1\frac{1}{4}$	0 $1\frac{1}{4}$
R.	0 $\frac{5}{16}$	0 $1\frac{3}{16}$	0 $1\frac{3}{16}$
S.	0 $1\frac{9}{16}$	0 $2\frac{1}{4}$	0 $2\frac{1}{4}$
T.	0 $1\frac{1}{2}$	0 $1\frac{3}{4}$	0 $1\frac{3}{4}$
U.	0 $\frac{7}{8}$	0 $1\frac{1}{4}$	0 $1\frac{1}{4}$
V.	0 $7\frac{3}{8}$	0 $11\frac{3}{4}$	0 $11\frac{3}{4}$

At the bottom of the cylinder is attached the new and improved release valve (fig. 81). The branch from the release valve is connected by a small hose pipe ($\frac{1}{2}$ in.) to the main train pipe B, or to a rapid-acting valve when latter is used on the equipment. Formerly the ball valve used with C-class cylinders was combined with the release valve, and sections of this are shown in fig. 84. It is of simple construction, there being only one moving piece, viz. a small brass ball, which in its normal position is on its seat closing a vertical passage leading to the vacuum chamber. The spindle, with release lever and actuating wires attached, is added for the purpose of withdrawing

the ball from its seat when it is required to release the brake by hand. The release lever spindle is made air-tight by a small diaphragm, the pressure on

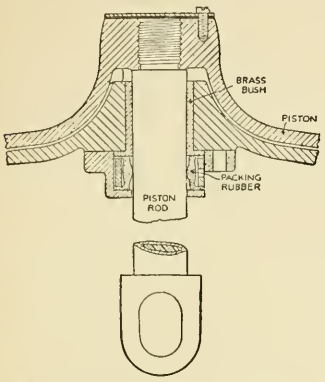


Fig. 83.—Piston Rod and Gland, Vacuum Brake

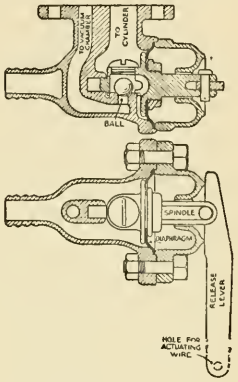


Fig. 84.—Ball Valve, Vacuum Brake

which, when a vacuum is created, pulls in the spindle and allows the ball to go freely to its seat.

The action of the C-class cylinder is as follows: The air is drawn out through the train pipe from the bottom of the piston *direct*, and from the top by passing the ball. To apply the brake the air is let into the train pipe, and it then passes to the under side of the piston (see fig. 85); and being prevented from entering to the top by the ball, lifts the piston and so applies the brakes, with a force in proportion to the quantity of air let in.

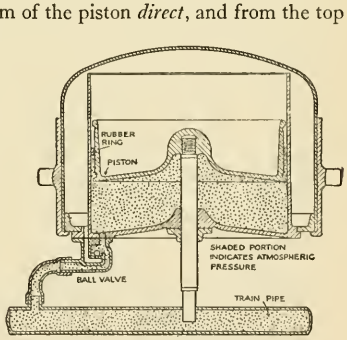


Fig. 85.—Illustration showing the Action of the Vacuum Brake

Guard's Van Valve (E) and Vacuum Gauge (F), fig. 81.—The van valve is fixed on the main train pipe, and enables the guard to apply the brake by pressing down the handle. It also opens automatically when the driver applies the brake suddenly, and admits air until the brake is fully applied. The valve has a small hole through its stem, and is secured at the top by a diaphragm to a small dome-like chamber, which chamber is exhausted when a vacuum is created in the train pipe. If a gradual application is made, the vacuum in this chamber is destroyed as quickly as in the pipe; but

when the brake is applied suddenly, the vacuum beneath the valve is destroyed much quicker, and then the pressure of the atmosphere on the diaphragm lifts the valve, which remains open until the vacuum is destroyed in the dome-like chamber by air entering through the small hole, then it closes by gravity. An enlarged view of the van valve is shown in fig. 86.

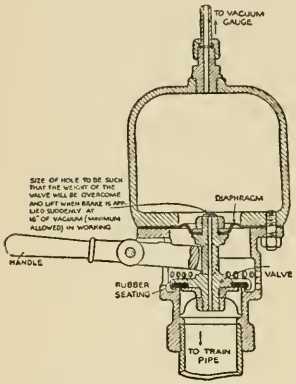

TO VACUUM GAUGE
SIZE OF HOLE TO BE SUCH THAT THE WEIGHT OF THE VALVE WILL BE OVERCOME AND LIFT WHEN BRAKE IS APPLIED SUDDENLY AT 15" OF VACUUM (MINIMUM ALLOWED) IN WORKING
DIAPHRAGM
HANDLE
VALVE
RUBBER SEATING
TO TRAIN PIPE

Fig. 86.—Guard's Van Valve, Vacuum Brake

The guard's vacuum gauge F, which is fitted close to the guard's seat and within his easy reach, is to indicate the amount of vacuum created in the train pipe and cylinders, and in running this varies from 18 to 25 in., a fair actual average being 20 in. A few words of explanation as to what this 20 in. really means will be of interest to general readers. When a partial vacuum is created in the train pipe and cylinders by the action of the ejector (and sometimes maintained by a pump) on the locomotive, the air remaining expands and reduces the pressure; and taking the ordinary atmospheric pressure in round figures at 15 lb. to the square inch, it means that for every 2 in. shown on the gauge we have reduced the pressure by 1 lb. to the square inch in the pipes, &c. Consequently at a reading of 20 in. we shall have only 5 lb. pressure remaining. Now when the brake is applied by admitting ordinary atmospheric pressure to the under side of the piston in the cylinder, we obtain (ignoring for the moment the loss through reduction of area in the vacuum chamber—see note on p. 199) a resultant power of 10 lb. to the square inch, i.e. the difference between 15 lb. outside and 5 lb. inside.

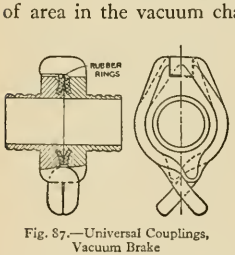


Fig. 87.—Universal Couplings, Vacuum Brake

The Universal hose couplings will be readily understood by reference to the drawing (G, fig. 81). They consist of a pair of castings, exactly alike, with horns top and bottom, making it impossible to couple them wrongly. To couple them, they should be lifted up sufciently high to enable the bottom horns to be placed together, and then lowered, the top lug of one being placed in the slot of the other. To uncouple, it is simply necessary to raise the couplings, when they will separate. Enlarged views of these couplings are shown in fig. 87. The dimensions of these couplings have recently been standardized on all railways.

Passenger Communication Valves; Slip Couplings.—This valve (fig. 88) is connected to the main train pipe, usually at the top of the end

bend, by a $\frac{3}{8}$-in. pipe (some companies use a slightly larger pipe); and the valve is so situated that the discs attached to the ends of the actuating rod come immediately under the cornices at the carriage end (see fig. 97, p. 200). The air in this small pipe is exhausted at the same time as the train pipe, and the upper end of the former terminates in the valve box with a $\frac{9}{16}$-in. nozzle, over which fits a leather cap secured to the metal flap worked by a cross-rod passing through the box. The rod, with discs, is attached to cranks enclosed in cases marked A at each side of the carriage (see fig. 97), and these cranks are connected to chains passing along inside the cant rails from end to end of the coach at both sides. The extreme ends of the chains are made tight at the opposite end of the carriage by means of adjustable nuts and screws. When the chain is pulled down in a compartment, it actuates the cranks and discs attached to the cross-rod, and also lifts the flap from the nozzle of the vertical pipe, which allows air to enter, and causes the vacuum to be partially destroyed, thereby denoting to the engine-driver and guard (through the medium of their gauges) that someone desires the train to be brought to a stand. The discs at the ends of the rods are painted red, and in their normal position are horizontal; but when actuated assume a vertical position, thereby informing the guard from which carriage the call came, while the slack chain in the compartment enables the officials to readily trace the source of alarm. After an alarm the disc is merely rotated by hand, which closes the valve and enables the vacuum to be again created. It is not desirable that the air inlet to the train pipe should be so large that the train will be brought to a stand directly the valve is actuated, as this might occur in very inconvenient places, such as long tunnels; and drivers are instructed to bring the train to rest at the nearest possible suitable place, for investigation to be made. For particulars of valve used on " dual "-fitted carriages see fig. 89.

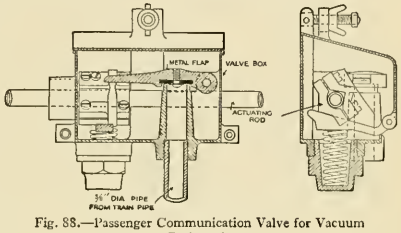


Fig. 88.—Passenger Communication Valve for Vacuum Brake only

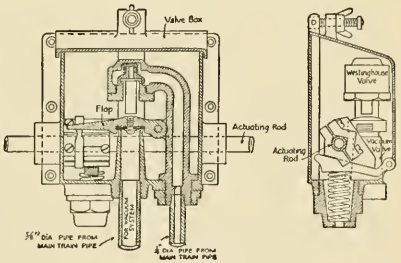
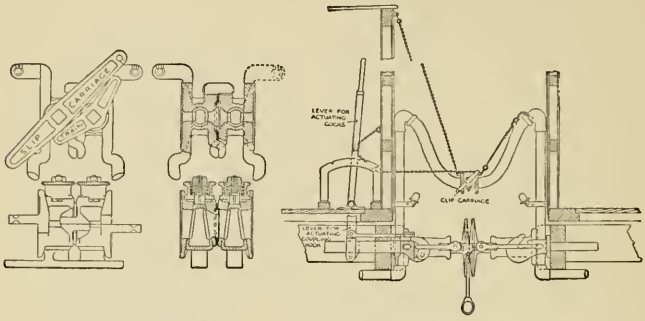


Fig. 89.—Passenger Communication Dual Valve for Coaches fitted with both Vacuum and Westinghouse Brakes

Full details of Gresham's patent slip couplings are shown in fig. 90, and also a sectional side elevation of two coaches when coupled together.

The interior interlocking fittings are given in fig. 48, with particulars of the "slip" draw gear. The object of these special cocks is to enable a vacuum to be maintained for emergencies on the slip vehicle, after the



Details of Slip Couplings — Sectional Side Elevation of Two Coaches coupled together

Fig. 90

first portion of the train has been disconnected; and the method of actuating the cock levers will be readily understood from the drawings.

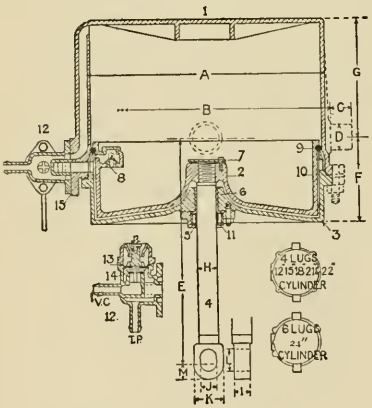


Fig. 91.—Separate Cylinder, "F-Class"

The above descriptions of vacuum automatic brake fittings represent most of those in use on British railways, but it should be understood that many of the items vary slightly on the different railways. It is also necessary to describe briefly and illustrate a few specialities which have been introduced within recent years in connection with this brake, but space will only permit the inclusion of those in fairly general use.

F-Class Cylinder; Rapid-acting Valves.—This cylinder (fig. 91) has been designed to facilitate the examination and renewal of the rolling ring, &c. It is fitted with a new type of release valve of a reversible pattern so that the latter can be turned round with the branch to train pipe for convenience in fixing. The cylinder is arranged with a bottom pan to enable the piston to be removed without taking the body of the cylinder down, and this is a good feature where

they are of large diameter and consequently heavy. Another improvement is the provision of a guide for the rolling ring, as should the latter get out of place the ring will be returned to its groove when the piston falls to its lowest position.

The following table gives the names of the various parts and the dimensions:

SEPARATE CYLINDER, "F-CLASS"

PATENT

LIST OF PARTS

1. Cylinder.
2. Piston.
3. Cylinder casing.
4. W. I. piston rod coated with brass.
5. Piston rod packing box.
6. Piston rod guide bush.
7. Piston rod cap.
8. Ball valve.
9. Rolling ring.
10. Joint ring.
11. Piston rod gland packing ring.
12. Reversible release valve.
13. Diaphragm for release valve.
14. Seating ring for release valve.
15. Insertion joint for release valve.

	Dimensions.																	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
Diameter	1	0	1	3	1	3	1	6	1	6	1	9	1	9	1	10	2	0	2	0
Stroke	0	6	0	9	0	8	0	9	0	8	0	9	1	0	0	9	1	0	0	9
A	1	$0\frac{3}{8}$	1	$3\frac{3}{8}$	1	$3\frac{5}{8}$	1	$6\frac{5}{8}$	1	$6\frac{5}{8}$	1	$9\frac{5}{8}$	1	$9\frac{5}{8}$	1	$10\frac{5}{8}$	2	$0\frac{5}{8}$	2	$0\frac{5}{8}$
B	1	$1\frac{3}{8}$	1	$4\frac{3}{8}$	1	$4\frac{3}{8}$	1	$7\frac{3}{8}$	1	$7\frac{3}{8}$	1	$10\frac{1}{4}$	1	$10\frac{1}{4}$	1	$11\frac{1}{2}$	2	$1\frac{1}{2}$	2	$1\frac{1}{2}$
C	0	$1\frac{1}{2}$	0	$1\frac{5}{8}$	0	$1\frac{5}{8}$	0	$1\frac{5}{8}$	0	$1\frac{5}{8}$	0	2	0	2	0	2	0	2	0	2
D	0	$1\frac{3}{8}$	0	2	0	2	0	2	0	2	0	2	0	2	0	3	0	3	0	3
E	0	$11\frac{7}{8}$	1	$5\frac{7}{16}$	1	$3\frac{1}{16}$	1	$5\frac{7}{16}$	1	$3\frac{1}{16}$	1	$5\frac{9}{16}$	1	$10\frac{1}{16}$	1	$6\frac{1}{16}$	1	$10\frac{1}{16}$	1	$7\frac{1}{16}$
F	0	$4\frac{1}{16}$	0	$6\frac{1}{2}$	0	6	0	$6\frac{1}{2}$	0	6	0	7	0	$8\frac{1}{2}$	0	7	0	9	0	$7\frac{1}{2}$
G	0	$5\frac{1}{8}$	0	$9\frac{3}{16}$	0	$7\frac{1}{16}$	0	$9\frac{3}{16}$	0	$7\frac{1}{16}$	0	$8\frac{3}{4}$	0	$11\frac{3}{4}$	0	$8\frac{3}{4}$	0	$11\frac{1}{4}$	0	$8\frac{1}{4}$
H	0	1	0	$1\frac{1}{2}$	0	$1\frac{1}{2}$	0	$1\frac{1}{2}$	0	$1\frac{1}{2}$	0	$1\frac{1}{2}$	0	$1\frac{1}{2}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$
I	0	$\frac{7}{8}$	0	$1\frac{1}{4}$	0	$1\frac{1}{4}$	0	$1\frac{1}{4}$	0	$1\frac{1}{4}$	0	$1\frac{1}{4}$	0	$1\frac{1}{4}$	0	$1\frac{1}{2}$	0	$1\frac{1}{2}$	0	$1\frac{1}{2}$
J	0	$\frac{13}{16}$	0	$1\frac{3}{16}$	0	$1\frac{3}{16}$	0	$1\frac{3}{16}$	0	$1\frac{3}{16}$	0	$1\frac{3}{16}$	0	$1\frac{3}{16}$	0	$1\frac{3}{16}$	0	$1\frac{3}{16}$	0	$1\frac{3}{16}$
K	0	$1\frac{1}{2}$	0	$2\frac{1}{4}$	0	$2\frac{1}{4}$	0	$2\frac{1}{4}$	0	$2\frac{1}{4}$	0	$2\frac{1}{4}$	0	$2\frac{1}{4}$	0	$2\frac{1}{4}$	0	$2\frac{1}{4}$	0	$2\frac{1}{4}$
L	0	$1\frac{1}{4}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$

The rapid-acting valve (Gresham's patent) shown in fig. 92 has been designed for long trains to give greater rapidity of application without

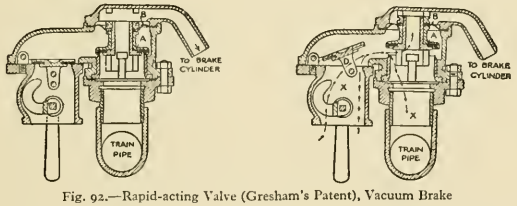


Fig. 92.—Rapid-acting Valve (Gresham's Patent), Vacuum Brake

causing unpleasant shocks to passengers, or possible breakage of the couplings. This valve is mounted on the train pipe as near as possible to the brake cylinder, and is connected to the ball or release valve by the usual

flexible hose pipe. A vacuum is maintained in the under side of the valve A and on the top side of the diaphragm B, the atmospheric pressure being free to operate on the top side of valve A and the under side of the diaphragm B. The excess pressure on the valve, over that on the diaphragm, holds the former tight on its seat. When these rapid-acting valves are required to work, a full application is made at the ejector, air being suddenly admitted to the train pipe and to the under side of valve A, when the pressure acting on the under side of the diaphragm is sufficient to cause it to lift the valve A and allow the air to pass freely both to the brake cylinder and to the train pipe (fig. 92). Immediately the brake is "full on", the valve falls to its normal position by gravity. The valve is so designed as to produce a simultaneous action of the brake on every vehicle throughout the train; and for gradual application, as in slowing down, air should be admitted only in moderate quantity to the train pipe. The clappet D performs three functions: (1) prevents dust accumulating on the valve casing; (2) in the event of a leakage it may be shut down by the lever, leaving the brake available for ordinary

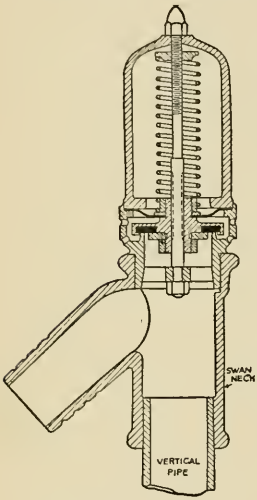


Fig. 93.—Rapid-acting Valve or "Accelerator", Vacuum Brake

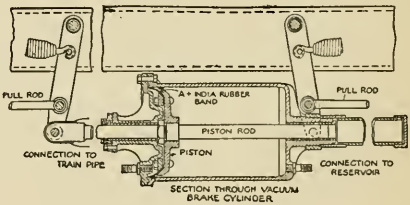


Fig. 94.—Horizontal Brake Cylinder, Vacuum Brake

use; and (3) it admits of the brake being used either as "rapid" or "ordinary" at a moment's notice. This "rapid-acting" valve has been more generally used for long goods trains fitted with the automatic vacuum brake.

Another rapid-acting valve or "accelerator", constructed by the Consolidated Brake and Engineering Company, is shown in fig. 93.

There are two types of this valve—one being adapted for fixing on the train pipe or on the siphon-seating leading direct to the cylinders, and the other intended for fixing on the end "swan neck" of the vertical pipe. In both cases the creation of a vacuum in the train pipe causes exhaustion in the upper chamber through grooves left on the outside of the diaphragm valve spindle; but the spiral spring within the chamber keeps the disc below the diaphragm on its seat until such time as a partial admission of

air to the train pipe destroys the vacuum existing above it, when it rises and admits air through the holes in the casing around it to the brake pipe and lower side of the brake cylinder, thereby giving a quick application of the brake to each vehicle so fitted.

Horizontal Brake Cylinder; High-speed Ball Valve.—A vacuum brake cylinder of a horizontal pattern has been introduced by Messrs. Holden & Brooke of Manchester, and is shown in fig. 94. This was designed more particularly for use where the vertical cylinder could not readily be fitted, owing to the structure of the underframe being unsuitable, and in this respect has been found of convenience when equipping goods vehicles hitherto fitted with hand brake only. With this cylinder no ball valve is required, as the rubber band (marked A on drawing) fulfils the same functions, and the vacuum chamber has an auxiliary reservoir connected therewith in a convenient position. When creating a vacuum, and in running, the band A readily allows air to pass from the reservoir and chamber, but makes a perfectly tight joint with the inside of cylinder directly air is admitted in the reverse direction, thereby applying the brake. It will be understood that the cylinder is so suspended horizontally as to admit of a double movement of both cylinder and piston rod. A small flap valve is provided for releasing the brake by hand when required.

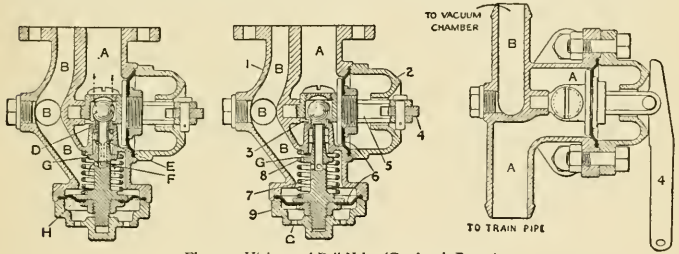


Fig. 95.—High-speed Ball Valve (Gresham's Patent)

The Vacuum Brake Company introduced some time ago an arrangement, intended for use on express passenger trains (which are generally composed of a number of heavy vehicles), so that the brake power might be a maximum when applied at high speed, and automatically reduced as the speed of the train decreased. This result was obtained by using, in place of the ordinary ball valve, the high-speed ball valve (shown in fig. 95) in connection with a rapid-acting valve and combined cylinder. With this arrangement it is usual to have an auxiliary reservoir of predetermined capacity. The action of the valve is as follows. The passage A is in communication with the bottom of the cylinder and the train pipe through the train-pipe branch. The passage B is connected with the top of the cylinder and vacuum chamber through the ball-seating and the holes E and F, and by the vacuum chamber branch, to the separate vacuum chamber in the

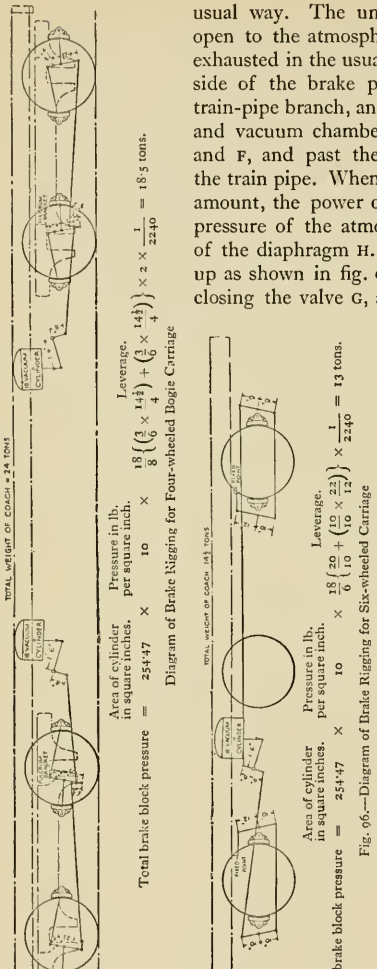


Diagram of Brake Rigging for Four-wheeled Bogie Carriage

$$\text{Total brake block pressure} = \text{Area of cylinder in square inches.} \times \text{Pressure in lb. per square inch.} \times \frac{18}{8}\left\{\left(\frac{3}{6}\times\frac{14\frac{1}{2}}{4}\right)+\left(\frac{3}{6}\times\frac{14\frac{1}{2}}{4}\right)\right\}\times 2\times\frac{1}{2240} = 18.5 \text{ tons.}$$

Diagram of Brake Rigging for Six-wheeled Carriage

$$\text{Total brake block pressure} = \text{Area of cylinder in square inches.} \times \text{Pressure in lb. per square inch.} \times \frac{18}{6}\left\{\frac{20}{10}+\left(\frac{10}{10}\times\frac{22}{12}\right)\right\}\times\frac{1}{2240} = 13 \text{ tons.}$$

Fig. 96.—Diagram of Brake Rigging for Six-wheeled Carriage

usual way. The under side of the diaphragm H is open to the atmosphere through the hole C. Air is exhausted in the usual way, and passes from the under side of the brake piston by the passage A and the train-pipe branch, and from the top of the brake piston and vacuum chamber by the passage B, the holes E and F, and past the ball to passage A, and thus to the train pipe. When the vacuum has reached a certain amount, the power of the spring is overcome by the pressure of the atmosphere acting on the under side of the diaphragm H. The centre spindle then moves up as shown in fig. 95, lifting the ball off its seating, closing the valve G, and opening the annular passage D. When the brake is applied, air enters by the train-pipe branch to the under side of the piston by the passage A and applies the brake in the usual way. It also passes by the annular passage D and the holes E and F into the passage B, and so to the top of the cylinder and vacuum chamber. When the vacuum in the chamber and on the top side of the piston has been reduced to a predetermined amount in a given time, the spring asserts its power and causes the hollow spindle to descend. This movement allows the ball to seat on its fixed seating, and prevents any further reduction in the chamber and the space above the piston. The middle view in fig. 95 shows the valve in the latter position.

Piston Stroke and Braking Power.—In the paragraph on the guard's vacuum gauge (p. 192) reference was made to the loss of power owing to the reduction of space in the vacuum chamber when the brake is applied; and from experiment with a vacuum of 20 in. it shows that a loss of approximately 5⅝ in. of vacuum and about 28 per cent of power will take place (where an 18-in. combined

cylinder only is used, without a reservoir) due to a stroke of 8 in. in applying the brake; but the latter figure, of course, in actual working is not permitted. General practice is for the brake blocks to be so adjusted as to give from $\frac{1}{8}$-in. to $\frac{3}{16}$-in. clearance when they are new or readjusted and this, with the levers so compounded as to give theoretically from 60 per cent to 80 per cent of the weight of the vehicle for braking power, will give a piston stroke of from $2\frac{5}{8}$ in. to $3\frac{3}{4}$ in. These figures include taking up of slack due to joints and the elongated hole at the bottom of the piston rod. In no case should the blocks be allowed to exceed $\frac{5}{16}$-in. clearance from wheels before readjustment, as with ordinary leverages this would give rise to an excessive stroke and consequent loss of power, as has just been mentioned.

The table appended gives some results obtained by actual tests of cylinders (no weight on piston), and will assist the reader to understand the foregoing. It also clearly shows the effectiveness of the higher vacuum.

15-in. Standard Vacuum Brake Company's Cylinder.			18-in. Standard Vacuum Brake Company's Cylinder.		
Stroke in Inches.	Loss in Chamber in Inches when Destroyed at 20 in. of Vacuum.	Loss in Chamber in Inches when Destroyed at 18 in. of Vacuum.	Stroke in Inches.	Loss in Chamber in Inches when Destroyed at 20 in. of Vacuum.	Loss in Chamber in Inches when Destroyed at 18 in. of Vacuum.
1	$\frac{5}{8}$	$\frac{3}{4}$	1	$\frac{1}{2}$	$\frac{5}{8}$
2	$1\frac{1}{8}$	$1\frac{1}{4}$	2	1	$1\frac{1}{8}$
3	$1\frac{3}{4}$	2	3	$1\frac{1}{2}$	$1\frac{5}{8}$
4	$2\frac{1}{4}$	$2\frac{3}{4}$	4	$2\frac{1}{8}$	$2\frac{7}{8}$
$4\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{8}$	$4\frac{1}{2}$	$2\frac{5}{8}$	$3\frac{1}{8}$
5	3	$3\frac{1}{2}$	5	3	$3\frac{1}{2}$
6	$3\frac{5}{8}$	$4\frac{3}{8}$	6	4	$4\frac{1}{2}$
7	$4\frac{3}{8}$	$5\frac{3}{8}$	7	$4\frac{7}{8}$	$5\frac{5}{8}$
8	$5\frac{1}{4}$	$6\frac{1}{2}$	8	$5\frac{5}{8}$	7
9	6	$7\frac{1}{2}$	9	$6\frac{5}{8}$	$8\frac{1}{2}$

NOTES.—Approximate readings in all cases, taken immediately pointer became steady.

Capacity of 15-in. cylinder = 2·381 c. ft.
Capacity of 15-in. cylinder at 3-in. stroke of piston = 2·081 c. ft.
Capacity of 18-in. cylinder = 3·196 c. ft.
Capacity of 18-in. cylinder at 3-in. stroke of piston = 2·756 c. ft.

Vehicles fitted with " through " pipes are only permitted to be attached to trains running 10 miles or under without a stop, in proportion 1 in 4, and to trains running over 10 miles without stoppage, 1 in 6. The end pipes of vehicles which have the gear complete are always painted black, but pipes not operating blocks are painted bright-red.

Fig. 96 is a diagram of the brake rigging for six-wheeled and four-wheeled bogie carriages. Although details differ on various companies' stock, the diagram will in general show how the theoretical calculations are arrived at, and will be of assistance to a student in working out similar examples.

Owing to the friction between the brake blocks and tyres being much less at high speeds than at low speeds, judicious application of the brake by the driver is very essential, and to assist in this matter some attention has recently been given to the provision of a mechanical improvement in the rigging, to automatically obtain a higher braking force strictly commensurate with the speed, viz. about 160 per cent of the weight of the vehicle for high speed, and gradually easing off to about 80 per cent as the train

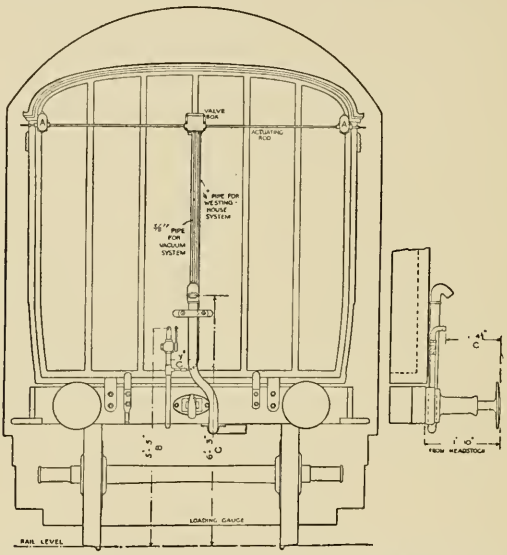
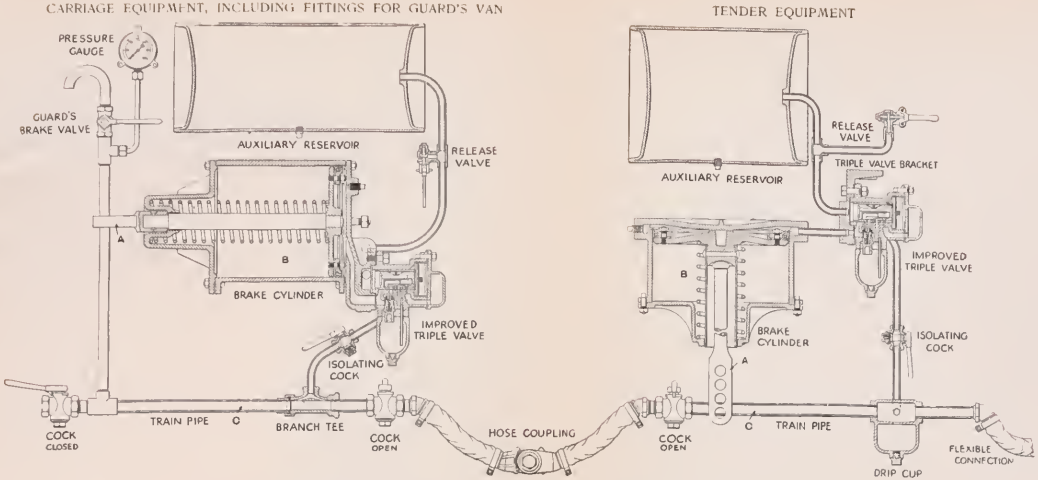


Fig. 97.—End Elevation of Coach fitted with Dual Brakes and Passenger Communication

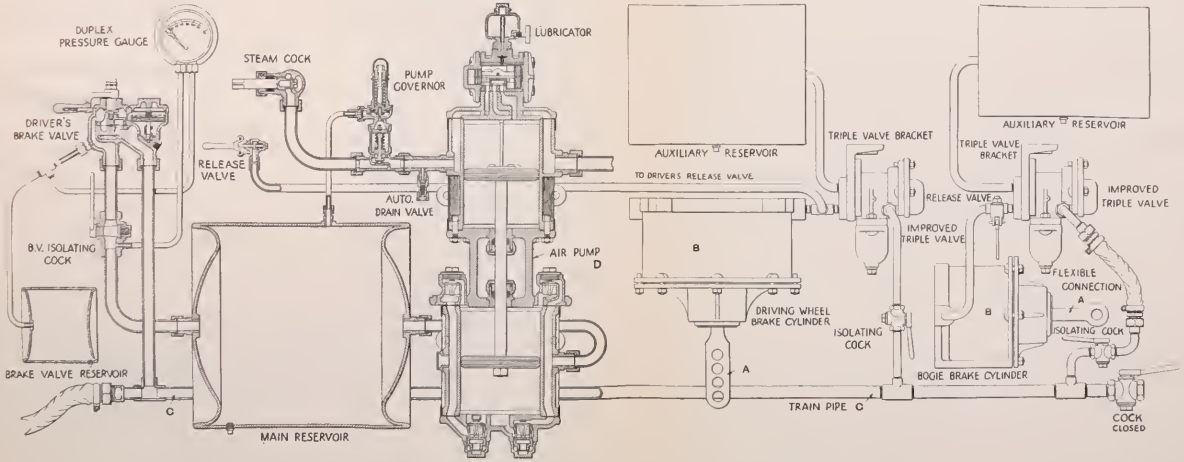
NOTE.—Both ends to be fitted alike. A deviation of 2″ is allowed in dimension marked C. A deviation of 1″ is allowed in dimension marked B.

comes to a standstill. This arrangement is known as the "Maximus" brake, and is under trial on several lines.

For many years schemes have been under consideration to automatically adjust the power of the brake on goods trains so that it may be equally efficient for loaded and unloaded vehicles without the danger of skidding when truck is empty. The Vacuum Brake Company accomplish this by adding to the usual brake equipment a special automatic valve (operated by hand from either side of vehicle) and a larger brake cylinder with separate reservoir. The brake gear is arranged that both cylinders are connected up to a common shaft so that one or both can exert a pull freely, and when the vehicle is loaded the special valve is operated to bring into action the large cylinder so that both may be used to give increased brake power, but should



ENGINE EQUIPMENT, INCLUDING BRAKE FOR LEADING TRUCK



GENERAL ARRANGEMENT OF WESTINGHOUSE BRAKE

[Facing p. 200, Vol. I

the truck have to be detached from a train the large cylinder will be automatically cut out, insuring that only the small brake cylinder is then available. The arrangement described has been fitted to a considerable number of bogie wagons in India, where high capacity trucks are extensively used.

Considerable difficulty was experienced until recently with coupling together the brake pipes of various companies' stock in interchange of traffic, this being due to the variation in height of the end pipes. In order to overcome this, a standard has now been agreed to by all companies, the full particulars of which are shown in figs. 97 and 98.

Westinghouse Brake.—A general description of the Westinghouse brake and its action is contained in the following paragraphs, reference being made by letters to the various parts on the diagram shown in Plate VIII. This brake stops the train by the application of brake blocks to the tyres, in the same way as the ordinary hand brake. The levers, however, which apply the blocks are moved by a piston A working in a cylinder, the piston deriving its power from air under pressure. It is continuous, each vehicle carrying its own brake cylinder B, which is connected to a pipe C running from end to end of the train, and it is through this pipe that the action of the brake cylinders is controlled. A pump D placed upon the engine compresses the air in the continuous pipe and cylinders; and so long as this pressure is maintained the brakes are kept off, but are instantly applied by letting the air escape from the train pipe either purposely or accidentally. The brake can be applied by the guard, and can be regulated to a nicety for easy stops or to control the train on an incline.

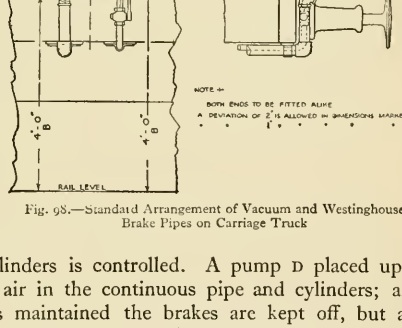


Fig. 98.—Standard Arrangement of Vacuum and Westinghouse Brake Pipes on Carriage Truck

Action.—The air pump, driven by steam from the boiler of the locomotive, compresses air to a pressure of from 90 to 100 lb. per square inch in the main reservoir, which should have a capacity of from 12 to 15 c. ft. for ordinary passenger service, and a greater capacity for exceptionally heavy service.

When the locomotive is coupled to the train, the compressed air in the main reservoir is turned into the train pipe, from which it passes through the branch pipes and fills the auxiliary reservoir on each vehicle. Thus the train pipe, the triple valves, and the auxiliary reservoirs are all charged with an equal pressure of air, which should be 70 lb. per square inch, or any higher pressure which may be adopted for normal working. This pressure is automatically maintained by means of the feed valve

attached to the driver's brake valve, but there is no compressed air in the brake cylinders so long as the brake is not in operation.

The brakes are applied to all the vehicles on the train by a reduction of pressure purposely (or accidentally) produced in the system. For ordinary stops 5- to 8-lb. reductions will suffice, whilst 25-lb. reduction will apply the brake with full force. In ordinary working this is effected by allowing air to escape to the atmosphere by the driver's brake valve or by the guard's emergency valve, but the same result follows if the train should part, or if a rupture of an essential part of the apparatus should occur on any vehicle. The reduction of pressure in the train pipe causes the pistons of all the triple valves to move, and permits a portion of the compressed air stored in the auxiliary reservoirs to be instantly discharged into the brake cylinders. This air forces the pistons forward, pressing the brake blocks against the wheels by means of the gear connected to the piston rod. The brake force thus produced corresponds with the reduction of pressure made in the train pipe, consequently the action of the brake can be graduated at will. The brakes are released by an increase of pressure in the main pipe, produced by admitting air from the main reservoir to the train pipe. This restores the pressure in the train pipe and returns the pistons of all the triple valves to their original positions. In this position the slide valves of the triple valves allow the air in the brake cylinders to escape to the atmosphere, so that the brake blocks are relieved of pressure, and the auxiliary reservoirs are at the same time recharged from the train pipe.[1]

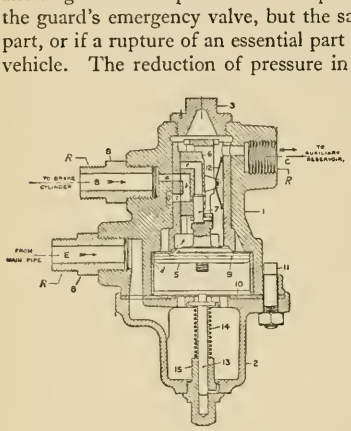


Fig. 99.—Ordinary Triple Valve, Westinghouse Brake

1, Top part with bushes. 2, Bottom part. 3, Upper brass cap. 5, Piston. 6, Slide valve. 7, Graduating valve. 8, Nipple. 9, Piston packing ring. 10, Leather gasket. 11, Bolt. 12, Slide valve spring. 13, Graduating stem. 14, Graduating spring. 15, Graduating stem guide.

The following is a detailed description of the fittings in general use on the carriages.

Ordinary Triple Valve (fig. 99).—The Westinghouse "ordinary" triple valve is operated by the variations of pressure in the main pipe, in such a manner that it automatically admits compressed air from the corresponding reservoir to the brake cylinder whenever the pressure in the main pipe is reduced, and discharges the compressed air from the brake cylinder when the original pressure in the main pipe is restored. The construction and mode of operation of this valve are as follows:

Enclosed in a case 1 is a piston 5, carrying with it a slide valve 6, which

[1] Release valve may discharge from brake cylinder or from auxiliary reservoir as preferred.

covers the port *a* to the brake cylinder, and in the position shown establishes a communication between port *a* and the atmosphere by the cavity *b* and exhaust passage *c*. Compressed air from the main brake pipe enters at E and, forcing up the piston 5, feeds past it through the groove *d* and passage C into the auxiliary reservoir, which is thus charged with an air pressure equal to that in the main brake pipe. The reservoir, triple valve, and main brake pipe then contain equal air pressure, and, so long as this is maintained, the brake remains out of operation.

Upon a reduction of pressure being made in the main brake pipe, the piston 5 will be moved downwards, owing to the excess of pressure now acting on its upper surface. The piston—having a limited movement without affecting the slide valve 6—closes the feed groove *d*, at the same time unseating the graduating valve 7, which thus opens the port *e*. The piston then also moves downwards the slide valve 6, which cuts off the communication from the cylinder to the exhaust port *c*, and opens the port *e* to the passage *a* leading to the brake cylinder, into which compressed air from the auxiliary reservoir immediately flows and applies the brake. The further downward movement of the piston 5 and slide valve 6 is arrested by the decrease of pressure above the piston, caused by the air flowing into the brake cylinder. So soon as the pressure in the reservoir is thus reduced a little below that in the main brake pipe, the piston 5 is moved up so far that it closes the graduating valve 7, while the slide valve 6 retains its position. By simply producing further reductions of pressure in the main brake pipe, the motion of the piston 5 and graduating valve 7 may be repeated, and the driver can thus gradually introduce any desired pressure into the brake cylinder, from zero up to the full power.

When a considerable reduction of pressure in the main brake pipe is suddenly made, the piston 5 is at once forced down to the limit of its stroke and seated on the leather gasket 10. The slide valve 6 then entirely uncovers the port *a*, so that the compressed air from the auxiliary reservoir flows into the brake cylinder with great rapidity, applying the brakes with full force.

To release the brakes, air is again admitted from the main reservoir to the main brake pipe. The air pressure, acting against the reduced pressure in the auxiliary reservoir, forces the piston 5 and slide valve 6 into the positions shown in fig. 99, thus permitting the air in the brake cylinder to exhaust through the port *c*, whilst at the same time the auxiliary reservoir is recharged through the feed groove *d*.

Quick-acting Triple Valve (fig. 100).—This valve forms the essential part of the quick-acting brake apparatus. It is operated by the variations of pressure in the main brake pipe in such a manner that it automatically admits compressed air to the brake cylinder of the vehicle to which it is attached whenever the pressure in the main brake pipe is reduced, and discharges the compressed air from the brake cylinder when the original air pressure in the main brake pipe is restored. The device consists of two piston valves, one working horizontally and the other vertically. The hori-

zontal main piston valve is in its construction and operation similar to that known as the " ordinary " triple valve.

In ordinary applications of the brake, only the horizontal main piston valve operates, admitting air from the auxiliary reservoir into the brake cylinder, whilst the secondary piston 13 and the valve 18 remain at rest. When, however, on a sudden reduction of the pressure in the main brake pipe, the piston 5 and its slide valve 6 are brought to their extreme position towards the right, compressed air is admitted to the upper side of the secondary piston 13, which, being driven down, opens the valve 18 and admits compressed air from the main brake pipe through the check valve 19 to the brake cylinder, which at the same time is also charged with compressed air, admitted by the slide valve 6, from the auxiliary reservoir. This discharge of air from the main brake pipe into the brake cylinders has the effect of reducing the pressure in that pipe with great rapidity, which causes a practically simultaneous action of the brakes, even on the longest goods trains.

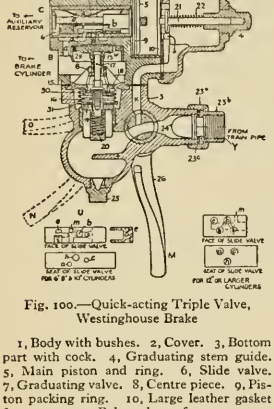

TO AUXILIARY RESERVOIR
TO BRAKE CYLINDER
FROM TRAIN PIPE
FACE OF SLIDE VALVE
SEAT OF SLIDE VALVE FOR 8" & 10" CYLINDERS
SEAT OF SLIDE VALVE FOR 12" & LARGER CYLINDERS

Fig. 100.—Quick-acting Triple Valve, Westinghouse Brake

1, Body with bushes. 2, Cover. 3, Bottom part with cock. 4, Graduating stem guide. 5, Main piston and ring. 6, Slide valve. 7, Graduating valve. 8, Centre piece. 9, Piston packing ring. 10, Large leather gasket for cover. 11, Bolt and nut for cover. 12, Slide valve spring. 13, Secondary piston. 14, Bolt and nut for bottom part (not shown). 15, Small leather gasket for bottom part. 16, Central valve washer. 17, Central valve stem. 18, Central valve bottom part. 19, Check valve. 20, Check valve spring. 21, Graduating stem. 22, Graduating spring. 23*a*, Union nut. 23*b*, Union nipple. 23*c*, Leather washer for union. 24, Strainer. 25, Drain plug. 26, Cock handle. 28, Exhaust nipple. 29, Secondary piston packing ring. 30, Large check valve spring. 31, Check valve spring washer. 32, Cock cap.

The construction and action of the quick-acting triple valve may be described as follows. Enclosed in a case 1 is a piston 5, carrying with it a slide valve 6, which covers the ports *a*, *c*, and *h*, in the valve case 1. When compressed air is allowed to flow from the main reservoir, through the driver's brake valve to the main brake pipe, it enters the triple valve on each vehicle at E, flows through the passages K and *l*, forces the piston 5 with the slide valve 6 to the position shown, and feeds past the grooves *d* and *f* into the auxiliary reservoir connected to C, which is thus charged with an air-pressure equal to that in the main reservoir. In this position of the piston 5 the brake cylinder is closed to the compressed air in the auxiliary reservoir by the slide valve 6, and to the air in the main brake pipe by valve 18, which is held to its seat by the pressure in the pipe. The same pressure now exists on both sides of the piston 5, and the brake is released, the brake cylinder being in connection with the atmosphere through the passages B and *a*, the cavity *b* in the slide valve, and the exhaust port *c*.

Moderate and Rapid Brake Applications.—When the brakes are to be moderately applied, as in ordinary stops, the " quick-acting " triple

valve operates in exactly the same way as the "ordinary" triple valve, the action being as follows. Upon a slight reduction of pressure being made in the main brake pipe, the piston 5, owing to the excess of pressure in the auxiliary reservoir, will move towards the right, thereby closing the feed groove *d*, and at the same time unseating the graduating valve 7, admitting air through a side aperture *m* in the slide valve to the passage *e*. The piston 5 then takes with it the slide valve 6, thus closing the communication from the brake cylinder to the atmosphere, and opening the passage *e* of the slide valve to the port *a* leading to the brake cylinder, into which compressed air from the auxiliary reservoir immediately flows and applies the brake. The further movement of the piston 5 and slide valve 6 is arrested by the decrease of the pressure on the left side of the piston, caused by the discharge of air from the reservoir into the brake cylinder. When the pressure in the reservoir is thus reduced a little below that in the main brake pipe, the piston 5 moves slightly back to the left, and closes the graduating valve 7, while the slide valve 6 retains its position. By simply regulating the reduction of pressure in the main brake pipe, and causing the motion of the piston 5 and graduating valve 7 to be repeated, the driver can gradually introduce any desired pressure into the brake cylinder, from zero up to full power.

When, however, it is necessary to apply the brakes quickly and with full force, rapid and considerable reduction of pressure is made in the main brake pipe, which causes the triple-valve piston 5 and its slide valve 6 to move to the limit of the stroke, the piston seating itself on the leather 10. Air from the auxiliary reservoir is then admitted through the recess *i* in the slide valve and the passage *h* to the secondary piston 13, which is thus moved down, forcing the valve 18 off its seat. The air pressure in the main pipe lifts the check value 19 and flows through the open valve 18 and passage B, into the brake cylinder. This has the double advantage of utilizing the air from the main brake pipe in the brake cylinders, and also, by the rapid reduction in the main brake-pipe pressure, of accelerating the application of the brakes to all the vehicles of the train with extraordinary rapidity, so as to ensure practically simultaneous action throughout trains of almost any length.

In the quick-acting position of the piston 5, the compressed air in the auxiliary reservoir is admitted above the secondary piston 13, as already described, and feeds through the small port *w* in that piston, and through the passage B into the brake cylinder, whilst the flow of air from the main brake pipe to the cylinder takes place through the valves 18 and 19. As soon as the pressure in the brake cylinder is equal to that in the main brake pipe, the check valve 19 is closed by the spring 20, thus preventing a return of air to the main brake pipe.

In order to release the brakes, compressed air from the main reservoir is admitted by means of the driver's brake valve into the main brake pipe, whence it enters the triple valve by the passages K and *l*, and forces piston 5 and slide valve 6 to their original position. In the course of this move-

ment the exhaust cavity *b* of the slide valve first connects the passage *h* to the exhaust port *c*, relieving the pressure from the top side of the piston 13, which is returned to the position shown, by the air pressure in the brake cylinder; whilst the spring 20 closes the valve 18. As the slide valve 6 completes its leftward movement, the cavity *b* also opens the passage *a* to the exhaust port *c*, which discharges the air from the brake cylinder and releases the brakes. The auxiliary reservoir is again charged as before described, through the grooves *d* and *f*. A wire gauze strainer 24 is inserted to prevent dirt or grit entering the valve.

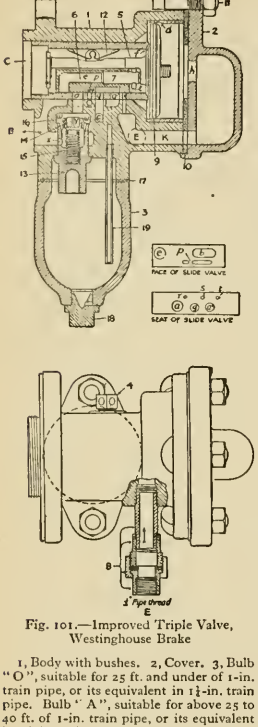


Fig. 101.—Improved Triple Valve, Westinghouse Brake

1, Body with bushes. 2, Cover. 3, Bulb "O", suitable for 25 ft. and under of 1-in. train pipe, or its equivalent in 1¼-in. train pipe. Bulb "A", suitable for above 25 to 40 ft. of 1-in. train pipe, or its equivalent in 1¼-in. train pipe. Bulb "B", suitable for above 40 ft. of 1-in. train pipe, or its equivalent in 1¼-in. train pipe. 4, Exhaust nipple. 5, Piston, with packing ring. 5*a*, Piston, with slide valve and graduating valve complete. 6, Slide valve. 7, Graduating valve. 8, ½-in. pipe nipple connection complete. 9, Piston packing ring. 10, Leather gasket for cover. 11, Bolt and nut. 12, Slide valve spring. 13, Regulating valve case. 14, Regulating valve. 15, Regulating valve spring. 16, Regulating valve cap. 17, Leather gasket for bulb. 18, Drain cap for bulb. 19, Siphon tube.

To secure the simultaneous release of the brakes, a nipple, having an aperture corresponding to the size of the brake cylinder with which it is used, is inserted in the mouth of the exhaust port of the triple valve.

By means of the cock in the lower part of the triple valve, the whole brake apparatus on a vehicle, or simply the quick-acting feature thereof, may be put out of use, without in any way affecting the action of the brakes on other vehicles of the same train. In the vertical position M of the cock handle, the quick action is in use; by turning it to N the brake is put out of operation entirely; whilst by turning still further to the position O, the quick action only is taken away, and the apparatus works in precisely the same manner as with the "ordinary" triple valve.

All triple valves are marked to show the size of brake cylinder with which they are intended to be used. Valves for horizontal brake cylinders are marked "6", "8", "10", &c., according to the size of the cylinder, whilst those for vertical brake cylinders are marked "7 v", "8 v", &c. When a triple valve is intended for use with two vertical brake cylinders, it is marked "$\frac{2}{10}$ V" or "$\frac{2}{13}$ V", &c.

Improved Triple Valve (fig. 101).—This valve has been designed to give a closer approach to simultaneous action of all the triple valves in a train than hitherto. In the figure the valve is shown in the release position,

and the bulb is open to the atmosphere. When the slide valve 6 is moved in applying the brakes, the bulb 3 is closed to the atmosphere and opened to the train pipe by the cavity *p* and port *s* shown in dotted lines. The local reductions of train-pipe pressure thereby produced by the forward triple valves in a train cause an earlier action of the rearward triple valves, which results in a more nearly simultaneous braking effect being produced throughout the train in every case of first setting the brakes than heretofore, with a smoother and more efficient brake service generally.

A further improvement, also tending to smooth and even action of all the brakes, is shown in the passage leading from port *a* in the seat of the slide valve 6 to the brake cylinder at B. It consists of a removable plug 13, perforated with holes *w* and *x*, which are always open, and an additional hole *y* carrying an automatic check valve 14, supported by a spring 15. It is so arranged that, when the brakes are first set, the automatic valve is opened against the spring resistance by the excess of air pressure above it, so that the hole *x* controls the rate of flow of air to the brake cylinder. As the air pressure on the under side of the valve increases, the spring closes the valve, when the smaller holes *w* control the rate of flow to the brake cylinder. The diameters of the regulating holes *w* and *x* are made proportional to the diameter of the brake cylinder with which the triple valve is to be used. By changing these perforated plugs, the same pattern of valve is thereby suited to cylinders of various sizes. The bulb at the bottom of the triple valve is made in different sizes, proportioned in cubic content to the volume of the train pipe of the vehicle on which the valve is to be used.

A separate passage *a'* is provided in the triple-valve body from brake cylinder to slide valve 6, for the air to escape from the brake cylinder on releasing the brakes. The rate of release is controlled, as heretofore, by a nipple (not shown) screwed into the outlet hole *c* in the triple-valve body.

Action of Improved Triple Valve.—The construction and action of the improved triple valve may be described as follows. Enclosed in the triple-valve body 1 is a piston 5, carrying with it a slide valve 6 which covers ports, *a*, *a'*, *g*, and *r*, *s*, *t* in the body 1. Port *a* admits air to the brake cylinder, and port *a'* is for the exhaust of the air from it through port *g* to the atmosphere by outlet *c*. Port *s* communicates with the bulb 3 through pipe 19, port *t* with the main brake pipe E, and port *r* with the atmosphere through outlet *n*.

When compressed air is allowed to flow from the main reservoir through the driver's brake valve to the main brake pipe, it enters the triple valve on each vehicle at E, flows through passages K and *h*, forces the piston 5 with its slide valve 6 to the position shown, and feeds past the grooves *d* and *f* into the auxiliary reservoir connected at C, which is thus charged with air at a pressure of about 70 lb. per square inch. In this position of the piston 5, the brake cylinder is closed to the compressed air in the auxiliary reservoir by the slide valve 6. The same pressure now exists on both sides of the piston 5, and the brake is released, the brake cylinder being in connection with the atmosphere through passages B, *a'*, the cavity *b* in the slide valve

6, and the exhaust port C. At the same time the bulb 3 is shut off from the main brake pipe E by the slide valve 6 covering port *t*, but is open through pipe 19, port *s*, and cavity *p* in the slide valve 6 to the atmosphere, through port *r* and outlet *n*.

Upon a reduction of pressure being made in the main brake pipe, the piston 5 will be moved to the right owing to the excess of pressure now acting on the other side. The piston, having a limited movement without affecting the slide valve 6, closes the feed groove *d*, at the same time unseating the graduating valve 7, which thus opens port *e*. The piston then in its further movement carries with it the slide valve 6, which first closes port *r*, thus cutting off the connection of the bulb 3 with the atmosphere; at the same moment port *s* is opened to the main brake pipe, and air from the main brake pipe fills the bulb 3 through pipe 19. This local reduction of pressure in the main brake pipe, due to the volume of air admitted to the bulb 3 at each triple valve, causes an immediate action of the next triple valve, in succession towards the rear of the train, which results in the practically simultaneous movement of all the pistons throughout the train. The piston 5, with valve 6, continues its movement until it reaches the limit of its stroke, the piston seating itself on the leather 10. Air from the auxiliary reservoir is then admitted past the graduating valve 7, through port *e*, passage *a*, and forcing the valve 14 off its seat, through passages *w*, *y*, and *x* in the regulating plug 13 to the brake cylinder by passage B. When the pressure in the auxiliary reservoir is reduced slightly below that in the main brake pipe, the piston 5 moves slightly to the left and closes the graduating valve 7, while the slide valve 6 retains its position. By simply regulating the reduction of pressure in the main brake pipe, and causing the motion of piston 5 and graduating valve 7 to be repeated, the driver can gradually increase the pressure in the brake cylinder up to the full pressure available.

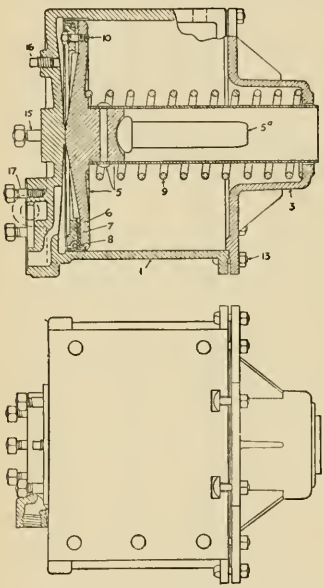


Fig. 102.—Horizontal Brake Cylinder, Trunk Piston Type, Westinghouse Brake

1, Cylinder body. 3, Dome head. 5, Piston and trunk. 5a, Push rod. 6, Piston follower. 7, Piston packing leather. 8, Piston packing expander. 9, Release spring. 10, Piston stud. 13, Cylinder head bolt. 15, Stud for bracket, with nut. 16, Plug. 17, Stud for triple valve, with nut.

In order to release the brakes, air from the main reservoir is admitted by means of the driver's valve into the main brake pipe, whence it enters the triple valve at E, flows through passages K and *h*, and forces piston 5 and slide valve 6 to their original position. In the course of the movement the exhaust cavities *b* and *p* in the slide valve connect port *g* with port *a'*, and port *s* with port *r*, respectively. The air from the brake cylinder and from the bulb 3 is then discharged to the atmosphere, and the brakes are released. The auxiliary reservoir is then recharged again through grooves *d* and *f*, as before described.

Brake Cylinders.—Figs. 102 and 103 illustrate two of the several

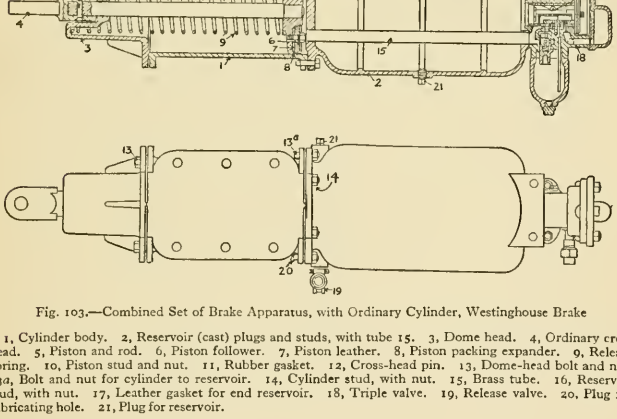


Fig. 103.—Combined Set of Brake Apparatus, with Ordinary Cylinder, Westinghouse Brake

1, Cylinder body. 2, Reservoir (cast) plugs and studs, with tube 15. 3, Dome head. 4, Ordinary cross head. 5, Piston and rod. 6, Piston follower. 7, Piston leather. 8, Piston packing expander. 9, Release spring. 10, Piston stud and nut. 11, Rubber gasket. 12, Cross-head pin. 13, Dome-head bolt and nut. 13*a*, Bolt and nut for cylinder to reservoir. 14, Cylinder stud, with nut. 15, Brass tube. 16, Reservoir stud, with nut. 17, Leather gasket for end reservoir. 18, Triple valve. 19, Release valve. 20, Plug for lubricating hole. 21, Plug for reservoir.

types of brake cylinders used for fitting rolling stock with the Westinghouse brake. All brake cylinders are so constructed as to avoid the use of stuffing boxes, which are difficult to keep in order and give rise to much trouble and annoyance.

To prevent the application of the brake from slight leakage in the main brake pipe or other fittings, there is cut in the body of each brake cylinder a small groove or passage, which establishes a communication between both sides of the piston when the brakes are " off ". If, on account of such leakage, the triple valve should permit a small flow of air from the reservoir to the brake cylinder, the air passes through these grooves to the atmosphere without moving the pistons; but on a reduction of pressure being made for the purpose of applying the brake, the pistons are immediately forced past the grooves, which are thus closed, and further escape of air from the cylinder is prevented. When fitting the brake gear, and at all subsequent

adjustments of the brake blocks, care must be taken to allow a sufficient travel of the piston to completely close the groove. The gear should be adjusted when the maximum stroke is reached.

The standard practice is to use vertical brake cylinders on locomotives and tenders, and this type is often used on horse boxes and vans, as shown in Plate II, p. 98. They are very convenient for coupling to existing hand-brake gear, especially when a rocking shaft is employed, since the trunk pistons permit the use of very short connecting rods, and allow ample lateral play when the brakes are applied. Although, in most cases, the brake gear will be simplified by fitting these cylinders vertically,

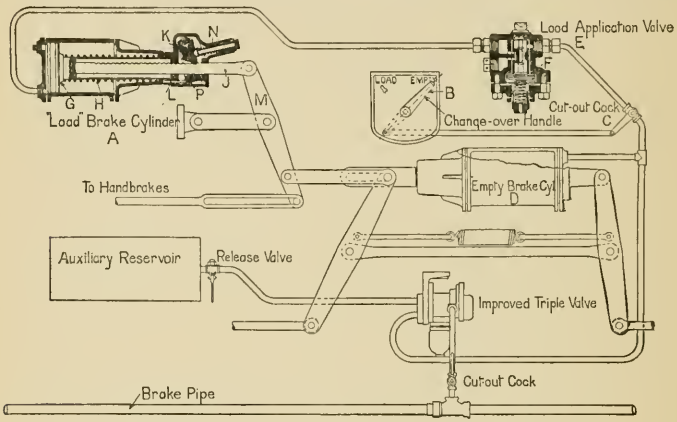


Fig. 104.—Diagrammatic Arrangement of Fittings and Connections, Empty and Load Brake

sometimes it may be advantageous to place them horizontally. For this purpose these cylinders may be supplied with special flanges. A cross-head is not used with vertical cylinders, but a push-rod end is supplied, to which a suitable eye or joint of the proper length for connecting to the brake gear should be welded.

It is frequently convenient to equip coaches with the combined type of cylinder in order to simplify the installation, as in this form the apparatus requires only one pipe connection, leading from the brake pipe to the triple valve. This type is shown in fig. 103.

Empty and Load Brake.—With goods and mineral wagons of high carrying capacity the total weight when loaded may be three or four times the weight when empty, consequently the brake power suitable for the empty wagon would be inadequate for it when loaded, and the arrangement shown in fig. 104 represents in diagrammatic form the fittings and connections required for the " empty and load " freight brake. The empty brake consists of the fittings comprising the automatic brake, with the usual cylinder

levers and their connections to the brake rigging, and is the normal brake when the car is empty.

The load brake cylinder also operates on a lever M, whose fulcrum is anchored to the car frame, the free end of this lever being connected to the empty brake cylinder lever at, or near, its crosshead. The hand brake may be conveniently attached to the load brake cylinder lever as shown.

The load brake cylinder A is brought into operation only when the operating lever B is moved over to the load position. In this position the isolating cock C is open and allows communication between the empty brake cylinder D and the load brake cylinder A, by way of the load brake application valve E. This valve is so arranged, that air is admitted to the load brake cylinder only when the pressure, during a brake application, has reached 24 lb. per square inch in the empty brake cylinder; when this takes place, the spring loaded piston F of the valve is moved over, the slide valve uncovering the passage to the load brake cylinder.

When the operating lever B is in empty position, the application valve, and therefore the load brake cylinder, are cut out of action.

The construction and operation of the load brake cylinders are as follows:

The piston G is provided with a trunk H, to the end of which is attached the piston rod locking mechanism. The push rod J is provided with notches into which the locking pawl K fits, but, so long as the piston G is in the position shown, the pin L operates to hold the pawl out of action, so that the push rod is free to move in and out of the cylinder when constrained to do so by the lever M during an empty brake application.

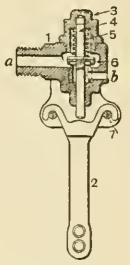


Fig. 105.—Release Valve (Westinghouse Brake)

1, Body complete with bush. 2 Handle. 3, Cap. 4, Valve. 5, Spring. 6, Valve packing leather. 7, Split pin.

When the load brake is in operation, the empty brake cylinder D first takes up the slack in the rigging, and the push rod J is moved out a certain distance by the lever M. The air, admitted by the application valve, entering the cylinder A, forces the piston G out, the first movement relieving the pressure from the pin L, which allows the wedge-shaped edge of the pawl to be forced, by the spring N, into the adjacent notch on the push rod, and the surface P to come into contact with the underside of the rod. The rod is thus firmly gripped by the locking mechanism, and the piston and push rod move out as a whole, thereby adding an increased force to the levers, and hence the breakshoes. Since all the slack has been taken up by the cylinder D, the cylinder A will have a piston travel of about 1½ in.

When the brake is released the piston G is moved back, carrying with it the locking mechanism and push rod until the pin L comes into contact with the cylinder end which disengages the pawl, thus permitting the push rod to be returned to its full release position by the movement of the lever M.

Release Valve—Hose Couplings.—A release valve (fig. 105) is fitted to each vehicle provided with brake apparatus, for the purpose of releasing

the brake by hand if applied when an engine is not connected to the train.

Light wires, or small chains, are attached to the handle 2, and fixed to the carriage frame, so that the valve may be opened by pulling from either side of the vehicle. When the handle 2 is thus moved the spindle of the valve 4 is lifted, and the air escapes by the passage *a* into the atmosphere through the hole *b*. So soon as the handle is set free the valve 4 is returned to its seat by its spring 5. To this end it is important that the wires or chains should not be made too heavy; also that they should be fastened in such a way as to work with perfect ease, and be free from liability to become frozen or clogged with snow. The valve is also furnished, if desired, with one vertical or two horizontal nipples.

Fig. 106 shows two coupling heads (one of them in section) united to form the connection of the main brake pipe between two vehicles. The two coupling heads, 1, 1, in either size are exactly alike, each being provided with a rubber packing ring 3, so arranged that when the couplings are united the rings face against each other and form an air-tight joint. The air pressure in the coupling tends to force these rings towards one another, so that the joint becomes tighter with increase of pressure. The tendency of the air pressure in the couplings is also to force them apart, in a direction at a right angle to the line of the indiarubber hosepipes, and, consequently, the greater the pressure the more firmly are the couplings held together by the projecting piece *g* of each coupling, which fits in a corresponding groove of the other coupling. No damage is done if the couplings be forcibly drawn apart by the separation of the train, as the rubber rings 3 are pressed into their respective couplings sufficiently far to permit the projections to disengage from their grooves. These couplings are united by simply placing them face to face at right angles, the stop pins being on the under side, and then turning the projection of the one into the groove of the other.

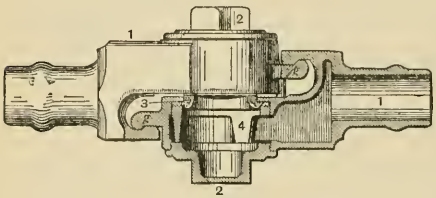


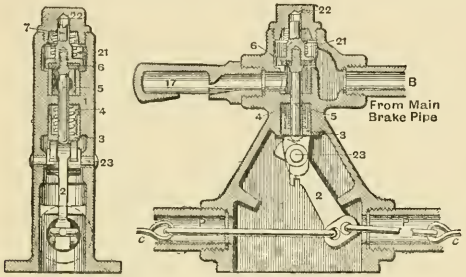
Fig. 106.—Coupling Heads (united) for Hose Couplings of Main Pipe (Westinghouse Brake)

1, Coupling case. 2, Coupling cap. 3, Coupling packing ring. 4, Ring holder.

As a protection from the weather, and from damage by oil, &c., the indiarubber hose is covered with a stout woven canvas sleeve, which is thoroughly painted to render it waterproof. Experience shows that hose so protected will, after several years' service, be found in a condition almost equal to new. When the coupling is out of use, it should be attached always to a dummy coupling to avoid dirt or sand collecting in it, which might afterwards be blown into the apparatus.

Passenger-communication Apparatus.—Fig. 107 gives complete

sectional views of the several parts of the passenger-communication apparatus. The two upper diagrams show the passenger-communication valve, with whistle, which is usually fixed on the roof of the carriage. The wire cord, on which the handles of the pull boxes ride, is fixed to the inner lever 2 of the communication valve, and by pulling down this cord the valve is opened, so that compressed air from the main brake pipe



Passenger-communication Valve

Piping B, P, and wire cord or chain C to be supplied by railway companies

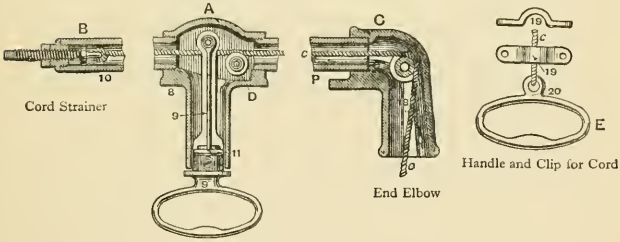


Fig. 107.—Passenger-communication Apparatus. (For Westinghouse Brake.)

1, Body of passenger-communication valve. 2, Lever. 3, Spring box. 4, Lever spring. 5, Valve stem; 6, washer; 7, valve top part—supplied complete in one piece. 8, Pull box. 9, Pull-box handle, complete. 10, Cord strainer, complete. 11, Rubber ring for pull-box handle. 17, Plug whistle. 18, End elbow. 19, Clip for cord. 20, Handle for end of cord. 21, Valve spring. 22, Cap.

flows to the whistle 17, which is thus sounded. To provide for closing the valve a second wire pull is fastened to the lever 2 and brought down at the end of the carriage within easy reach of the guard. The chief object of the whistle 17 is to facilitate the detection of the carriage on which the apparatus has been used, which otherwise would cause undue delay, especially at night.

When screwing a pull box A to the carriage roof, the end containing the pulley D must be turned towards the passenger-communication valve. A shows the complete pull box with handle, which is so fixed on the roof

of the vehicle that the handle projects inside the compartment, where it should be within easy reach of the passengers. When the handle 9 is pulled down, the communication valve is opened and the brake applied. B represents the cord strainer, which is attached to the pull box of the end compartment, for adjusting the wire cord on which the handles ride. C shows a cross section of the end elbow, which serves to guide and protect the cord in passing over the edge of the roof at the end of the vehicle. E represents a clip and handle for the cord hanging at the end of the vehicle.

British companies using the Westinghouse system generally adopt the communication valve shown in fig. 108, which is fixed at the end of the coach

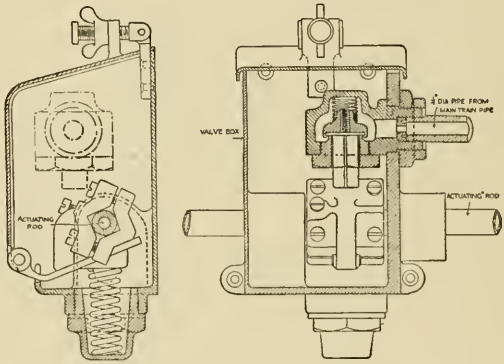


Fig. 108.—Passenger-communication Valve (Westinghouse Brake only)

similarly to the one used in connection with the vacuum brake, and is actuated by a rod (fitted with discs) in the same manner.

Hand Brakes.—Hand brakes are mainly of two types, "screw" and "side lever". The former is generally used on all passenger and goods brake vans where the application is to be made from inside the vehicle; and the latter for practically all other stock where in shunting operations it may be quickly applied from the side of the vehicle. Heavy bogie wagons with a high carrying capacity are an exception to the last clause, as it is not convenient to get sufficient braking power with the side-lever arrangement, and a screw gear actuated from the side is used instead.

A general form of screw hand brake for vans may be seen in Plate IV, A, p. 102, of the 56-ft. steel underframe, and is the arrangement used on the 56-ft. third brake carriages on the London and South-Western Railway. The hand wheel is 16 in. diameter and the screw $1\frac{1}{2}$ in. diameter, having a double-thread $\frac{3}{4}$-in. pitch. This drives an 8 in. $\times$ 18 in. bell crank, which is connected by a floating lever and rods to the 10- and 8-in. levers on the main rocking shafts. The hand brake actuates all the sixteen brake

blocks, giving a theoretical power of 288 to 1. To prevent a train leaving a station with the hand brake on, and thereby causing hot tyres and possibly serious damage, a " Tell-tale " Indicator has recently been introduced by the Vacuum Brake Company which indicates by a tablet on the side of the vehicle whether the brake is " on " or " off ". The action is such that, so long as the hand brake is " on ", a valve remains open and prevents a sufficient vacuum being created; and with the pressure brake the escape of air would cause an audible signal, at once attracting attention to the hand brake being " on ". Side-lever hand brakes in conjunction with power brakes are illustrated on the underframes shown in Plate II (facing p. 98) of the underframe for a 21-ft. horse-box, and it will be seen that by a simple clutch arrangement the levers are both right-handed, conforming to the Board of Trade[1] rule. (See Clause 1 of Schedule 1, p. 216.)

Board of Trade Action affecting Brakes.—With regard to hand brakes for wagons, it is necessary before stating the present practice to give, as briefly as possible, the reasons for this practice. In general all wagon stock was hitherto fitted with a brake applying two blocks, one to each pair of wheels, and actuated by one long side lever, the latter being secured in the " on " position by a pin and chain or a notched rack. This arrangement led to many accidents, which were due to the fact that men frequently ran in front of a truck when shunting, to get to the side where the hand lever could be put down, and, further, to crawling between wagons to release the brake if they were on the wrong side. The problem of inventing a satisfactory brake which could be applied from either side and released from either side, irrespective of the side on which it was applied, has been given the greatest attention by railway companies and inventors for many years past, and hundreds of thousands of pounds have been spent in experiments to this end. In 1906 the Board of Trade appointed a special committee (known as the Railway Employment Safety Appliance Committee) to deal with such matters. The Committee at once took this brake question in hand, and from time to time carried out exhaustive trials of the various either-side brakes submitted to it. Briefly the result may be stated in the following paragraph, which the writer quotes from the report of the Committee, dated May, 1907: " The whole of the either-side brakes claiming to conform to those conditions may be said to have come under review, but in no instance has the appliance proved itself to possess sufficient merit to enable us to recommend that its general adoption be made compulsory ". Following this the Committee drew up certain proposed rules, one of which was that all either-side brakes on existing wagons were to be removed within a period of ten years, and this rule, if it had been made compulsory, would have been very costly to companies having a very large number of wagons so fitted. The Great Western Company, which had equipped several thousands of wagons with the Dean and Churchward patent either-side brake, successfully appealed against this proposed rule, proving by expert evidence that,

[1] During the war the functions of the Board of Trade were transferred to the Ministry of Transport.

although this brake did not satisfy the Committee, it had given good results in actual working.

The following are the Board of Trade rules relating to wagon brakes. They came into operation in November, 1911.

1. No wagon constructed after the expiration of six months from the coming into operation of this Rule shall be received or used for traffic on any railway unless it is fitted on both sides with brake levers complying with the conditions set out in the Schedule No. 1 to this Rule.

2. Within the periods prescribed in Clause 3 all wagons now existing or constructed before the expiration of the six months above mentioned and not so fitted, shall be fitted on both sides with brake levers complying with the said conditions, and thereafter no such wagon shall be received or used for traffic on any railway unless it is so fitted.

3. The periods prescribed for the purposes of Clause 2 shall be from the date of this Rule:

10 years for companies or persons owning under 3000 wagons.
15 years for companies or persons owning 3000 and under 20,000 wagons.
20 years for companies or persons owning 20,000 wagons and over.

In any case, where it is shown to the Board of Trade that for any sufficient cause the time within which any of the above provisions have to be carried into effect

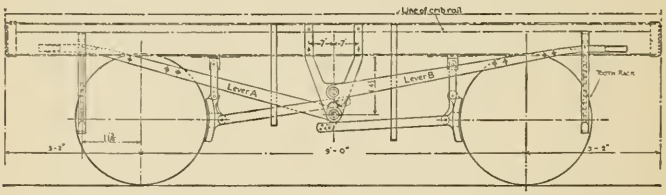


Fig. 109.—Arrangement of "Morton" Type Right-handed Wagon Brake, with Two Brake Blocks only

should be extended, the Board of Trade may from time to time grant such extension upon such terms and conditions as it may think fit.

4. The wagons specified in the Schedule No. 2 hereto are exempted from the operation of this Rule.

5. This Rule shall come into operation as from the date hereof, and may be cited as the Prevention of Accidents Rules, 1911.

Schedule No. 1

1. The levers to be of like pattern, and to be so placed that each shall be to the right of a man facing the side of the wagon.

2. Each lever to be so fitted that sufficient brake power can be conveniently applied with one hand.

3. The levers to be so fitted that the brakes can be released only from the side on which they have been applied.

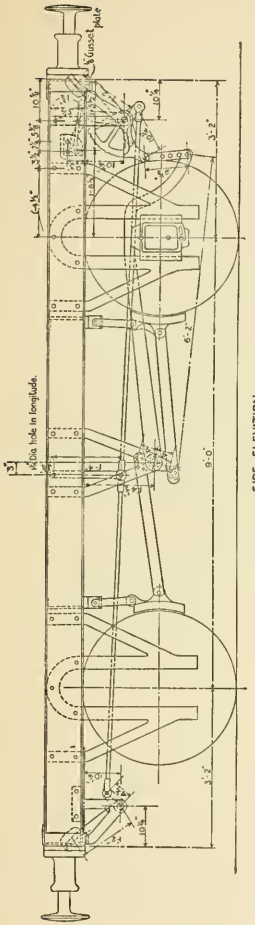


Fig. 110.—General Arrangement of Dean and Churchward Brake on London and South-Western Railway 10-ton Wagon

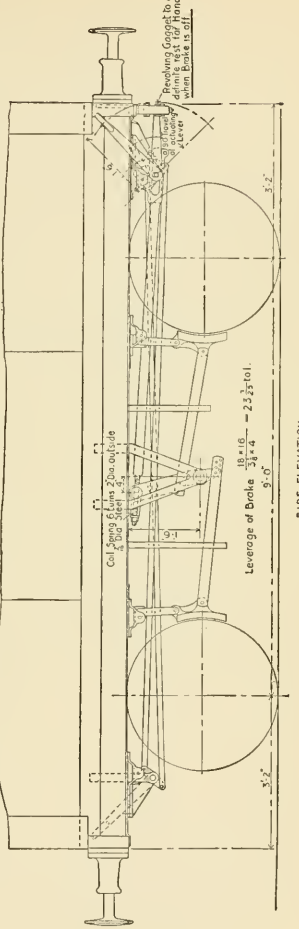

Revolving Gaggot to give 4 positions of Handle when Brake is off
Coil Spring 6 Coils 2¼ outside
Leverage of Brake 18×16 / 3/4×4 = 23 3/25 tol.
SIDE ELEVATION

Fig. 111.—Arrangement of Trampton's Patent Either-side Wagon Brake

4. The levers to be " press down and lift up ", and to be provided in the " off " position with a stop.

5. Articles 3 and 4 of this Schedule shall not apply to brakes of which the design has been approved by the Board of Trade.

SCHEDULE No. 2.—EXEMPTIONS FROM THE RULE

(*a*) Wagons used upon railways of a gauge less than 4 ft. 8½ in.

(*b*) Chaldron wagons of a carrying capacity of 5 tons or less.

(*c*) Wagons of a carrying capacity of over 20 tons.

(*d*) Boiler wagons.

(*e*) All wagons fitted with the Dean and Churchward brake, as described in Specification No. 202, of 1902, if arranged as a cross-cornered brake.

(*f*) Any wagons with regard to which compliance with this Rule is, in the opinion of the Board of Trade, unnecessary or impracticable.

Provided that all wagons exempted under *c*, *d*, and *f* are fitted on both sides with such other appliances as will enable sufficient brake power to be conveniently applied from either side, if, in the opinion of the Board, such other appliances are necessary.

Examples of Either-side Brakes.—It will now be seen that the latest requirements are for the brakes to be applicable from either side, but only capable of being released from the side on which applied. Fig. 109 probably shows the cheapest form of brake which complies with this rule, and is what is known as a "Morton" brake. Some companies prefer that the work done by the side lever B be obtained by means of an additional fulcrum and a link working on to a loose lever on the shaft; as by this arrangement the wear of the engaging portions of clutch and side lever is prevented. Some companies fit the wagons with two complete sets of brake gear, but this adds both to weight and cost.

Illustrated in fig. 110 is the Dean and Churchward brake, as exempted by Clause *e* of Schedule 2; and as a further example of an either-side brake, which has been in work for several years with excellent results, the writer illustrates in fig. 111 Frampton's wagon brake. It will be seen on reference to the drawing that this brake possesses the desirable feature of being capable of being graduated for use on inclines, and also has a definite rest for the handles when the brake is "off".

CHAPTER X

Wagons and Miscellaneous Types of Stock

Railway companies' wagons and those belonging to private traders represent a very large portion of the capital laid out on rolling stock in this country, and with several companies the receipts from goods and mineral traffic are the chief sources of income. It will be understood, therefore, how important it is that these vehicles should be strongly constructed and maintained in an efficient manner for the work they have to do, and that constant examination should be carried out. Further, the enormous number of private owners' wagons running upon the various

lines rendered it very necessary, not only in the interest of public safety, but for the protection of the railway companies themselves, that all private owners' new wagons should be subject to most careful inspection and registration before being permitted to be sent into general traffic on the lines of railway.

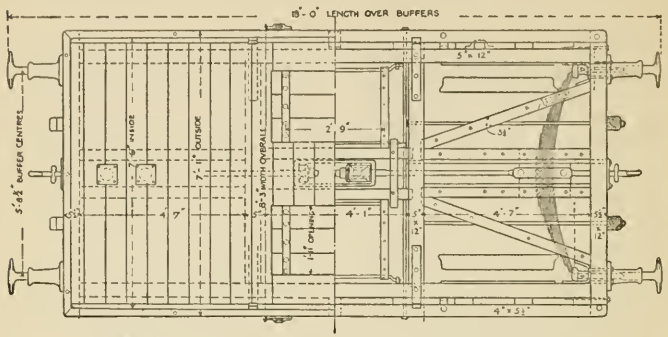
In 1887 the railway companies unanimously decided to carry out such inspection and registration of private wagons, this decision being the outcome of a report and suggestion made to the Board of Trade by Major Marindin, R.E., with reference to an accident which occurred at Penistone on the 1st January, 1885, where, owing to the breaking of an axle belonging to an empty coal wagon, great damage was done, and serious loss of life occurred. This inspection and registration has since been carried out and extended to include reconstructed and " converted " wagons, the latter expression being used to designate trucks which formerly had dead or solid buffers and were afterwards fitted with self-contained buffers of an elastic type. It may be noted here, that on and after the first day of January, 1914, dead-buffered wagons were not allowed to travel upon the railways in Great Britain, the owners of such trucks having had ample time and opportunity afforded them to effect the conversion. The definition of a reconstructed wagon was as follows. When a dead-buffered wagon was so far worn as to require the following new members, viz. two new solebars, or one new solebar and three cross members, the wagon had to be reconstructed, the limit of time between the replacement of the solebars or main members being one year. The wheels and ironwork could be used again, provided they complied with certain specified conditions.

Specifications for Private Owners' Wagons.—The standard specifications and drawings for private traders' wagons were drawn up jointly by the technical experts of all the railway companies of Britain, and it will therefore be conceded that they are thoroughly representative in character, and ensure that private owners when buying trucks receive good and substantial wagons from the builders. The original specification of 1887 was only for wagons with carrying capacity of 10 tons or under, but from time to time these specifications have been so enlarged that at present they provide for the building of 8-, 10-, 12-, 15-, 20-, and 30-ton trucks, and also for the various forms of tank wagons for the conveyance of liquids, and did up to 31st December, 1914, provide for the reconstruction and conversion of wagons as mentioned above. Wagons previously registered might be rebuilt when the truck was so far worn as to require the renewal of the same members referred to for the reconstruction of dead-buffered wagons. There can be no doubt whatever that the standardization of the strength of the parts used in the construction of private owners' wagons, and their inspection before being permitted to run, has saved many serious accidents, and, in addition, has effected much good by the companies themselves conforming as far as possible with the standard laid down for the private owner.

There is a great variety of wagons running in Britain, but general prac-

tice and much detailed information is given in the following paragraphs, which deal with the leading types of trucks.

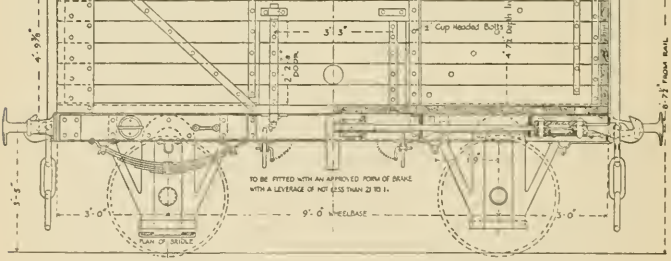
Modern requirements for ordinary short wagons will be represented by



Half Plan of Body — Half Plan of Underframe

Fig. 112.—Standard Private Owners' 10-ton Wagon with Wood Body and Underframe

stating the present specification and illustrating two types of private owners' 10-ton wagons, one with wooden underframe (fig. 112) and the other with steel underframe (fig. 113), both having side and bottom doors. The specification (given below) also applies to 8- and 12-ton trucks, the only



Half Side Elevation — Half Longitudinal Section

Fig. 113.—Standard Private Owners' 10-ton Wagon with Wood Body and Steel or Iron Underframe

difference being that the bearing springs and axles of the latter are somewhat stronger than for the 10-ton truck (see Clauses 11 and 16). For wagons required to be built with an end door the arrangement is as shown in fig. 114. Eight-ton new wagons are now seldom built, and the same

remark applies to steel underframes for wagons, it having been found that unless the steel frames are kept efficiently painted the corrosion will in course of a fairly short time seriously deteriorate the strength of the parts (see p. 184). The wooden frame lends itself more readily for repairs whether required by wear and tear or as the result of an accident.

The workshop practice for preparing and putting together both wood and steel frames of wagons is similar to the descriptions given in the chapter

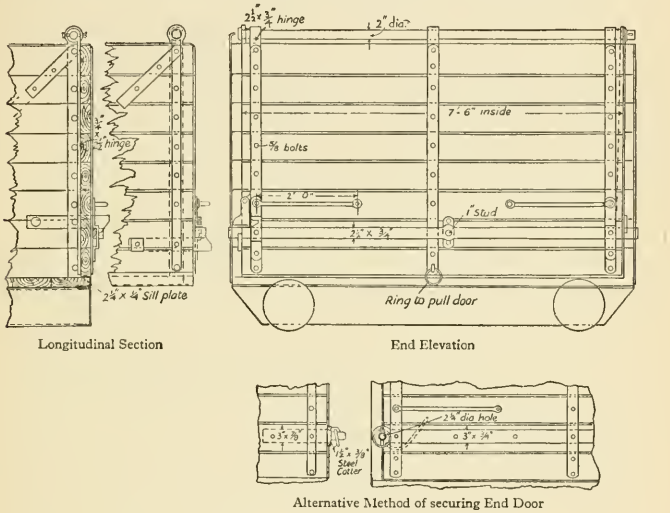


Fig. 114.—Arrangement of End Door on Private Owners' Wagon

on underframes. For vehicles with covered bodies the framing is dealt with somewhat similarly to that described for coachwork (see Chapter VII), the main difference being that the bodies are not built separately, but direct on the frames.

Specification for 10-ton Wagon.—The following is the standard specification for private owners' 10-ton wagons:

1. *Dimensions.*—No wagon to exceed 8 ft. 6 in. wide over all, nor to exceed in height 10 ft. at the sides and 11 ft. 6 in. in the middle above the top of the rails. (No wagon for tipping coal at Roath Dock, Cardiff, must be of a greater width than 8 ft. 3 in., and for other Bristol Channel ports not to exceed 8 ft. $4\frac{1}{2}$ in.)

The length of coal wagons not to exceed 16 ft. 6 in. over headstocks.

Coke wagons may be made 17 ft. 6 in. over headstocks.

The wheel base not to be less than 8 ft. nor to exceed 9 ft.

The load not to exceed 8, 10, or 12 tons respectively, and the building of 8-ton wagons to be limited as much as possible.

2. *Tare.*—Maximum tares:

	Single-spoke wheels with wrought-iron centres 2½-in. sheeting.				Open-spoke wheels with wrought-iron centres 2½-in. sheeting.			
	10 Tons.		12 Tons.		10 Tons		12 Tons.	
	tons.	cwt.	tons.	cwt.	tons.	cwt.	tons.	cwt.
Side only	5	19	6	7	6	2	6	10
Side and bottom ..	6	1	6	9	6	4	6	12
Side and end ..	6	2	6	10	6	5	6	13
Side, end, and bottom	6	4	6	12	6	7	6	15

Extra to the above, the tares may be increased:

For 3-in. sheeting, 3 cwt.
For coke rails, 6 cwt.
For 2½-in. tyres, 3½ cwt.
For oak frames, 2 cwt.
For pitch-pine sheeting, 2 cwt.
For commode rod and steps, ½ cwt.
For hinged top planks, 1 cwt.
For coke wagons of full length, 2 cwt.
For additional single brake, 3½ cwt.
For a " Morton " brake, 2 cwt.
For large drawbar cradles, large drawbar spring and stop, additional rubber springs and plates, additional plates in buffing springs, lengthened buffer cylinders, increased width of end door latch bar, ⅝-in. bolts in body and bolted spring shoes = 1½ cwt.
For 10-ton coke wagons having a capacity of not less than 500 c. ft. exclusive of the coke rails, 5 cwt.

The maximum tares allowed for wagons for traffic on the Barry, Port Talbot Railway and Docks, Rhondda and Swansea Bay, Rhymney and Taff Vale Companies' lines are as follows:

10-ton wagons maximum tare.			12-ton wagons maximum tare.	
tons.	cwt.		tons.	cwt.
6	7	....	6	15

3. *Body.*—The bodies of the wagons may be made of wood, iron, or steel.

For wood bodies, 2½-in. or 3-in. sheeting of approved quality may be used.

Commode rods, buffer steps, and brake racks to be fixed as required on end-tipping wagons for the Bristol Channel Ports.

4. *Underframes.*—The underframe to be of steel, iron, or wood, and the members to be so prepared that the ends have a good bearing on the adjacent parts.

The dimensions of the principal members of steel or iron underframes to be as follows:

Headstocks and solebars ..	9-in.-by-3-in.-by-$\frac{3}{8}$-in. channel bars.
Trimmers	6-in.-by-3$\frac{1}{2}$-in.-by-$\frac{1}{2}$-in. ,,
Middle bearers	8-in.-by-3$\frac{1}{2}$-in.-by-$\frac{1}{2}$-in. angle bars; or 9-in.-by-3-in.-by-$\frac{3}{8}$-in. channel bars.
Diagonals and longitudinals	6-in.-by-3$\frac{1}{2}$-in.-by-$\frac{3}{8}$-in. angle bars.
End stanchions	5-in.-by-3$\frac{1}{2}$-in.-by-$\frac{1}{2}$-in. tee bars.
Curb rails for wagons with wood bodies	7-in.-by-3-in.-by-$\frac{3}{8}$-in. 9$\frac{1}{2}$-in.-by-3-in.-by-$\frac{3}{8}$-in. 3-in.-by-3-in.-by-$\frac{5}{16}$-in. special angle bars; or special angle bars riveted to $\frac{3}{16}$-in. plate.
End rails for wagons with wood bodies	3-in.-by-3-in.-by-$\frac{5}{16}$-in. special angle bars.

Wood underframes to be of sound white oak, or other timber not less in strength and quality than white oak, the dimensions of the principal members being as follows:

Solebars	12 in. by 5 in., or if with steel or iron plate $\frac{5}{16}$ in. thick; the full depth and length of solebar, 12 in. by 4$\frac{1}{2}$ in.
Headstocks	12 in. by 5$\frac{1}{2}$ in.
Crossbearers	12 in. by 5 in.
Longitudinals and diagonals	12 in. by 3$\frac{1}{2}$ in.

5. *Doors.*—Horizontally hung side doors when down must clear rail level by 8$\frac{1}{2}$ in. with the wagon unloaded, and vertically hung doors when open must not extend beyond 6 ft. 6 in. from the centre of the wagon.

Bottom doors must, when down and the wagon unloaded, clear the rail level by 7 in.

6. *Draw Gear.*—The draw gear throughout to be made of Grade A iron (British Standard Specification), or mild weldable steel, of Government chain-proof quality, and to be continuous and elastic, and of the dimensions shown on the Standard Drawings. The drawbar pins to be of steel of the same quality as the tyres (42 to 48 tons tensile). The bars from which the coupling links are made to be 1$\frac{1}{2}$ in. in diameter, and the chains to hang loosely in the drawbar; all links to be welded at the side. Two per cent of the chains to be tested, if required, and to withstand a breaking strain of 60 tons.

When couplings are worn below 1$\frac{3}{16}$ in. in thickness at the ends they must be removed.

7. *Axleguards.*—The axleguards to be made of 3$\frac{3}{4}$-in.-by-$\frac{3}{4}$-in. iron, and the wings to be 2$\frac{1}{2}$ or 3 in. by $\frac{3}{4}$ in.; the bottom stay or bridle to be 2 in. by $\frac{5}{8}$ in. or other approved design.

Each axleguard must be securely attached to the underframe by, in the case of steel or iron frames, 7 rivets or bolts $\frac{7}{8}$ in. diameter; and, in the case of wood frames, 7 bolts $\frac{7}{8}$ in. diameter. Bolts to have oval necks.

8. *Brake.*—Each wagon to be fitted with a double-block brake having a cast-iron block applied to one wheel of each pair, and a leverage of not less than 21 to 1, and so that the handle of the lever shall not project more than 7 in. beyond the headstock; each brake to have also a lever guard with a pin and chain (which in its lowest possible position shall not hang lower than 6 in. above the running rail) or rack for holding the lever down. Safety loops must be applied to the brake

gear as shown on Standard Drawing. Split pins to be used outside all nuts on brake rigging.[1]

9. *Buffers.*—Laminated buffing springs to be used; the buffers to be 18 in. in length from headstock to face, which is to be 12 in. in diameter; the centres to be 5 ft. 8½ in. apart, and 3 ft. 5 in. high from top of rails when the wagon is unloaded.

10. *Buffing Springs.*—The buffing springs to be made of fourteen plates of 3-in.-by-½-in. steel. The spring buckles must be forged or made from the solid from Class B steel (25 to 32 tons tensile) capable of withstanding a pull of not less than 65 tons. They must be made in accordance with the Standard Drawing.

11. *Bearing Springs.*—For 8- and 10-ton wagons the bearing springs to be made of either 5 plates 4-in.-by-⅝-in. steel, or 9 plates 4-in.-by-½-in. steel; and for 12-ton wagons either 5 plates 4-in.-by-⅝-in. steel, or 10 plates 4-in.-by-½-in. steel; and to be fitted with a wrought-iron hoop 3 in. by ½ in., with ½-in. rivet in middle, or a flat rivet of equal strength.

The bearing springs to be secured in position by bolts and nuts, as shown on the Standard Drawings.

Split pins to be used outside all nuts.

12. *Axleboxes.*—The axleboxes to be of good strong iron or steel (cast or pressed), and to have bronze or gun-metal bearings well fitted in. The grease chamber to have a capacity of about 100 c. in., and the lid to be made of wrought or malleable cast iron well fitted, and with a spring upon it; a ⅞-in. bolt to go through the axlebox underneath the centre of the journal. The top of the axlebox to be so formed that the bearing spring will "bed" into it 2 in.

Shepherd's Patent wrought-iron or mild-steel drop forged and welded axleboxes (see description page 130) may also be used.

Other approved axleboxes may be used for either grease or oil.

An efficient shield to be put in the back of the box to keep out dust.

Each axlebox must have cast or stamped upon the front the size of the journal for which it is constructed.

12-ton wagons to be fitted with oil axleboxes of approved pattern; but, if desired, 12-ton wagons used for tipping coal, &c., may have grease axleboxes.

The bearings for oil axleboxes for 12-ton wagons to be roughly bored and then lined with approved anti-friction metal having a minimum thickness of $\frac{3}{16}$ in.

13. *Tyres.*—The tyres to be made of acid or basic open-hearth or acid Bessemer steel (British Standard Specification, No. 5A, Class B).

The tyres to be 5 in. wide, and not less than 2 in. nor more than 2½ in. thick on tread when finished, truly bored out, with not more than $\frac{1}{16}$ in. allowance for contraction. Tyres to be secured to the wheels by the method of fastening shown on the Standard Drawings.

Tyres for 8-, 10-, and 12-ton ordinary wagons and 10-ton tank wagons must not be turned below $1\frac{1}{16}$ in. on tread, and for 15- and 20-ton ordinary wagons, and 12-, 14-, and 20-ton tank wagons, not below $1\frac{5}{16}$ in. on tread.

14. *Axles.*—The axles to be made of acid open-hearth or basic open-hearth steel (British Standard Specification, No. 3).

Wrought-iron axles will be accepted where required, provided they pass the following tests, and on the understanding that when a specification for iron axles is issued by the British Standards Committee the tests provided therein will be substituted:

[1] The Board of Trade new rules having now come into operation, double brakes must be provided.

Tensile Test.—A test piece of half a square inch area cut from any part of the axle tested or from the ends left on the forgings to give an ultimate strength of not more than 23 tons and not less than 20 tons per square inch, with not less than 25 per cent elongation measured over a parallel length of 3 in.

NOTE.—The axles must also comply with the falling-weight test.

15. *Axles, 8- and 10-ton Wagons.*—For 8- and 10-ton wagons the axles to be 6 ft. 6 in. in length from centre to centre of journals; $5\frac{1}{4}$ in. in diameter through the boss of the wheel, and gradually tapered to $4\frac{1}{2}$ in. in the middle. There must be no shoulder on the axle behind the boss. The journals to be 8 in. long by $3\frac{3}{4}$ in. in diameter.

Axles are to be discarded when the journals are, in the case of 8-ton wagons, worn below $3\frac{3}{8}$ in., and in the case of 10-ton wagons below $3\frac{1}{2}$ in. in diameter.

16. *Axles, 12-ton Wagons.*—For 12-ton wagons the axles to be 6 ft. 6 in. in length from centre to centre of journals, $5\frac{1}{2}$ in. in diameter through the boss of the wheel, and gradually tapered to $4\frac{7}{8}$ in. in the middle. There must be no shoulder on the axle behind the boss. The journals to be 9 in. long by $4\frac{1}{4}$ in. in diameter.

Axles under 12-ton wagons are to be discarded when the journals are worn below $3\frac{7}{8}$ in. in diameter.

17. *Wheels.*—The body of the wheel to be made of wrought iron with eight solid or open spokes, or of mild steel or cast steel with eight solid spokes, to the dimensions shown on the Standard Drawings.

All wheel skeletons to be turned exactly to 2 ft. 9 in. in diameter.

The bosses must be bored out, and the wheels then forced untired on to the axle by hydraulic pressure of not less than 50 tons for 8- and 10-ton wagons, and 60 tons for 12-ton wagons. If tyred wheels are forced on the axle, the pressures must be not less than 60 tons and 70 tons respectively.

No keys are to be used.

18. *Bolts and Nuts.*—All bolts and nuts to be screwed to Whitworth Standard Thread, and, wherever practicable, all nuts and cotters must be placed outside, so as to be easily seen.

19. *Quality of Wrought Iron or Steel.*—All steel or wrought iron used in the construction of wagons under this specification to be, unless otherwise specified, to the quality, and to withstand the tests set forth in the Standard Specification and Tests for Materials to be used in the construction of private owners' wagons.

20. *Stamping of Iron Work and Steel Work.*—All iron work and steel work as far as practicable to be stamped distinctly with the name or initials of the builder or owner.

The top side planks of the wagon shown in fig. 113, p. 220, are carried through from end to end; but as the arrangement is sometimes very inconvenient for loading and unloading at the side doors, it is permissible for these top planks to terminate at either side of the doorway, and for vertically hung doors or hinged planks to be fitted in place thereof. It may be added that the through top side planks are a considerable source of strength to the wagon, and should be retained whenever possible.

If it is necessary for a wagon to be sheeted when loaded, an arrangement for carrying the tarpaulin is made of 2-in. tubing bent to the required

shape, with solid ends welded on. The carrier is capable of being radiated from brackets fixed on the ends of the wagon, so that the support may rest on the sides of the truck when not in use.

Specification for 15-ton Wagons.—Fifteen-ton wagons are being fairly extensively built both by the railway companies and for private traders; and although the former seldom require to load them to their full carrying capacity (excepting with coal), they are found to be very economical for working between certain points where there is constantly a large quantity of medium-weight articles to be conveyed. In such cases full advantage can be taken of the additional cubic capacity. With but little variation, the dimensions of the standard private owners' 15-ton wagon (see fig. 115)

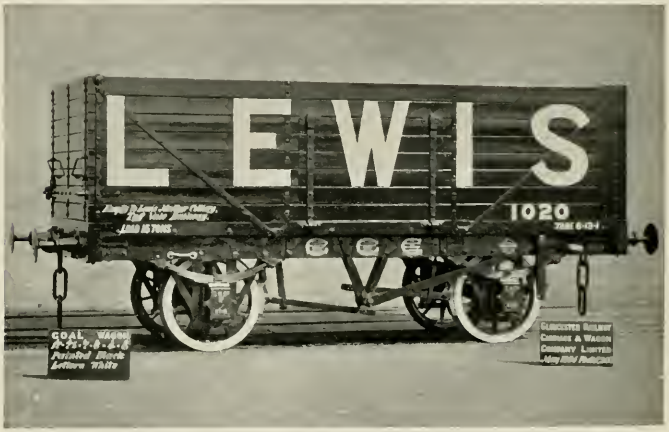


Fig. 115.—Private Owners' 15-ton Wagon

apply to these trucks as built by the railway companies for their own use. The underframe is generally of wood with $\frac{5}{16}$-in. steel sole plates, but steel channels may be used throughout if preferred. The wagon may be fitted with an end door if required.

The specification for this truck is the same as for 10-ton trucks, with the following exceptions:

1. *Dimensions.*—Length not to exceed 18 ft. outside body, and wheel base not to be less than 9 ft. 6 in. nor to exceed 10 ft.

2. *Maximum Tares.*

Doors.	Wagons with $2\frac{1}{2}$-in. Sheeting
Side only	7 tons 4 cwt.
Side and bottom	7 tons 6 cwt.
Side and end	7 tons 7 cwt.
Side, end, and bottom	7 tons 9 cwt.

Extra to the above, the tares may be increased:

For 3-in. sheeting	$3\frac{1}{2}$ cwt.
For oak frames	$2\frac{1}{2}$,,
For pitch-pine sheeting	$2\frac{1}{2}$,,

3. *Underframe.*—The dimensions of the principal members of steel or iron underframes to be as follows:

Headstocks and solebars ..	10-in.-by-$3\frac{1}{2}$-in.-by-$\frac{3}{8}$-in. channel bars.
Trimmers	6-in.-by-$3\frac{1}{2}$-in.-by-$\frac{1}{2}$-in. channel bars.
Middle bearers, diagonals, and longitudinals ..	9-in.-by-4-in.-by-$\frac{1}{2}$-in. angle bars, or 9-in.-by-3-in.-by-$\frac{3}{8}$-in. channel bars.
End stanchions	5-in.-by-$3\frac{1}{2}$-in.-by-$\frac{1}{2}$-in. tee bars.
Curb rails for wagons with wood bodies	7-in.-by-3-in.-by-$\frac{3}{8}$-in special angle bars, or $9\frac{1}{2}$-in.-by-3-in.-by-$\frac{3}{8}$-in. special angle bars, or 3-in.-by-3-in.-by-$\frac{5}{16}$-in. special angle bars riveted to $\frac{5}{16}$-in. plate.
End rails for wagons with wood bodies	3-in.-by-3-in.-by-$\frac{5}{16}$-in. special angle bars.

Wood underframes to be of sound white oak, or other timber not less in strength and quality than white oak, the dimensions of the principal members being as follows:

Solebars	12 in. by $5\frac{1}{2}$ in., or if with steel or iron plate $\frac{5}{16}$ in. thick; the full depth and length of solebar, 12 in. by 5 in.
Headstocks and crossbearers	12 in. by $5\frac{1}{2}$ in.
Longitudinals and diagonals	12 in. by $3\frac{1}{2}$ in.

4. *Axleguards.*—The axleguards to be made of 4-in.-by-$\frac{3}{4}$-in. iron, and the wings to be $2\frac{1}{2}$ in. by $\frac{3}{4}$ in. or 3 in. by $\frac{3}{4}$ in., the tie-rod to be 2 in. by $\frac{5}{8}$ in. or of other approved design. Each axleguard must be securely attached to the underframe by, in the case of steel or iron frames, 7 rivets or bolts $\frac{7}{8}$ in. in diameter; and, in the case of wood frames, by 7 bolts $\frac{7}{8}$ in. in diameter. Bolts to have oval necks.

5. *Brake.*—Brake leverage to be not less than 25 to 1.

6. *Buffers.*—Buffer heads to be 13 in. in diameter.

7. *Bearing Springs.*—The bearing springs are to be made of 6 plates of 4-in.-by-$\frac{5}{8}$-in. steel; to have $4\frac{3}{4}$ in. of camber, unweighted, and to be fitted with a wrought-iron hoop 3 in. by $\frac{1}{2}$ in., with $\frac{1}{2}$-in. rivet in middle, or flat rivet of equal strength.

8. *Axleboxes.*—Oil axleboxes to be used, except that, in the case of tipping wagons, grease boxes may be fitted. The bearings for oil axleboxes to be as specified for 12-ton wagons.

9. *Axles.*—The axles to be 6 ft. 6 in. in length from centre to centre of journals, $5\frac{3}{4}$ in. in diameter through the boss of the wheel, and gradually tapered to 5 in. in the middle. There must be no shoulder on the axle behind the boss. The journals to be 9 in. long by $4\frac{1}{2}$ in. in diameter.

Axles are to be discarded when the journals are worn below $4\frac{1}{4}$ in. in diameter.

Private Owners' 20-ton Wagon (see fig. 116).—Up till now these trucks have not been extensively built, the 10-ton trucks having found most favour with private traders.

Fig. 116.—Private Owners' 20-ton Wagon

The specification for these vehicles is the same as for the 10-ton trucks, with the following exceptions:

1. *Dimensions.*—Length not to exceed 21 ft. 6 in. outside body. The wheel base for the length quoted to be 12 ft., and for the shorter wagons to be proportionately reduced, 10 ft. being the minimum.

2. *Maximum Tares.*

Doors.	Wagons with 2½-in. Sheeting.
Side only	8 tons 9 cwt.
Side and bottom	8 tons 11 cwt.
Side and end	8 tons 12 cwt.
Side, end, and bottom	8 tons 14 cwt.

Extra to the above, the tares may be increased:

For 3-in. sheeting	4 cwt.
For pitch-pine sheeting	3½ ,,
Hinged top planks	2 ,,

3. *Underframe.*—The underframe to be of steel or iron, and the members to be so prepared that the ends have a good bearing on the adjacent parts.

The dimensions of the principal members to be as follows:

Solebars	10-in.-by-3½-in.-by-½-in. channel bars.
Headstocks, diagonals, longitudinals, and middle bearers	10-in.-by-3½-in.-by-⅜-in. channel bars.
Trimmers	6-in.-by-3½-in.-by-½-in. channel bars.
End stanchions	5-in.-by-3½-in.-by-½-in. tee bars.
Curb rails for wagons with wood bodies	7-in.-by-3-in.-by-⅜-in. special angle bars, or 9½-in.-by-3-in.-by-⅜-in. special angle bar, or 3-in.-by-3-in.-by-$\frac{5}{16}$-in. special angle bar riveted to $\frac{3}{16}$-in. plate.
End rails for wagons with wood bodies	3-in.-by-3-in.-by-$\frac{5}{16}$-in. special angle bars.

4. *Axleguards.*—The axleguards to be made of 4-in.-by-⅞-in. iron, and the wings to be 2½ in. by ⅞ in.; the tie-bar to be 2½ in. by ⅝ in. or of other approved design. Each axleguard must be securely attached to the frame by 7 rivets or bolts, ⅞ in. diameter; rivet holes to be $\frac{15}{16}$-in. diameter. Bolts to have oval necks.

5. *Brake.*—Each wagon to have a four-block brake with leverage not less than 30 to 1.

6. *Buffers.*—Buffer heads to be 13 in. in diameter.

7. *Bearing Springs.*—The bearing springs to be made of 7 plates of 4-in.-by-⅝-in. steel; to have 6½ in. camber, unweighted, and to be fitted with a wrought-iron hoop 3 in. by ½ in., with ½-in. rivet in middle, or a flat rivet of equal strength.

8. *Axleboxes.*—Oil axleboxes to be used, made of cast steel or, alternatively, they can be of wrought-iron or mild-steel drop forgings welded (Shepherd's Patent). The bearings to be roughly bored and then lined with approved anti-friction metal, having a minimum thickness of $\frac{3}{16}$-in.

9. *Axles.*—The axles to be 6 ft. 6 in. in length from centre to centre of journals, 6¾ in. in diameter through the boss of the wheel, and gradually tapered to 6 in. in the middle. There must be no shoulder on the axle behind the boss. The journals to be 10 in. long by 5 in. in diameter. Axles are to be discarded when the journals are worn below 4⅝ in. in diameter.

Private Owners' 30-ton Wagon. The type of bogie usually used under these trucks is given in fig. 16, p. 118. The specification for these wagons is the same as for the 10-ton truck, with the following exceptions:

1. *Dimensions.*—Length not to exceed 32 ft. outside body, nor to exceed 8 ft. in width over all.

The centres of bogies to be not less than 7 ft. from the face of the buffers (the face of buffer to face of headstock being 1 ft. 6 in.), and the distance between the centres of bogies under any one wagon not to be less than 15 ft.

The wheel base of bogies to be 5 ft. 6 in.

2. *Maximum Tare.*

Doors.	Wagons with 2½-in. Sheetings.
Side only	14 tons 1 cwt.
Side and bottom	14 tons 5 cwt.

Extra to the above, tares may be increased:

For 3-in. sheeting	6 cwt.
For $2\frac{1}{2}$-in. tyres	7 ,,
For pitch-pine sheeting	5 ,,
For hinged top planks	4 ,,

3. *Underframe.*—The underframe to be of steel or iron, and the members to be so prepared that the ends have a good bearing upon the adjacent parts.

The dimensions of the principal members to be as follows:

Solebars, headstocks, longitudinals, and bolsters	10-in.-by-$3\frac{1}{2}$-in.-by-$\frac{3}{8}$-in. channel bars.
Diagonals	6-in.-by-$3\frac{1}{2}$-in.-by-$\frac{1}{2}$-in. channel bars.
Middle bearers for wagons with wood floors	6-in.-by-$3\frac{1}{2}$-in.-by-$\frac{3}{8}$-in. angle bars.
Middle bearers for wagons with steel floors	4-in.-by-5-in.-by-$\frac{1}{2}$-in. tee bars.
End stanchions	5-in.-by-$3\frac{1}{2}$-in.-by-$\frac{1}{2}$-in. tee bars.
Curb rails for wagons with wood bodies	7-in.-by-3-in.-by-$\frac{3}{8}$-in. special angle bars.
End rails for wagons with wood bodies	3-in.-by-3-in.-by-$\frac{5}{16}$-in. special angle bars.

4. *Bogies.*—For bogies of the diamond type the arch bars to be 5 in. by $1\frac{3}{8}$ in.; inverted arch bars to be 5 in. by $1\frac{1}{4}$ in., and the pedestal tie-bars to be 5 in. by $\frac{3}{4}$ in.—all to be bolted together through pedestals by $1\frac{1}{2}$-in. bolts, and through axleboxes with $1\frac{1}{8}$-in. bolts.

The spring plank to be 1-ft.-1-in.-by-$3\frac{1}{2}$-in.-by-$\frac{7}{16}$-in. channel bar; the bolster to consist of two angle bars 6 in. by 6 in. by $\frac{7}{16}$ in., trussed with a plate 11 in. by 1 in.

The bogie centre and side bearings to be stamped or cast as per drawings.

Other approved bogies may be used.

5. *Brake.*—Each wagon to be fitted with an approved brake, with a cast-iron block on each wheel.

6. *Buffers.*—The buffer heads to be oval, 1 ft. 5 in. by 1 ft., horizontal and vertical axes respectively.

7. *Bearing Springs.*—The bearing springs (helical) for diamond bogies to be in clusters, two being used for each bogie. Each cluster to consist of four springs.

Diameter of spring, $5\frac{7}{16}$ in.; section, $1\frac{3}{16}$ in. diameter.
Height of spring (light), $8\frac{1}{4}$ in.
Height of spring (solid), $6\frac{9}{16}$ in.

For other bogies, springs to be as shown in the Standard Drawing of 15-ton wagon, except camber free to be $3\frac{1}{8}$ in.

Split pins to be used outside all nuts in cases where laminated side-bearing springs are used.

8. *Axleboxes.*—Oil axleboxes to be used. They are to be of good strong iron or steel (cast or pressed), or, alternatively, can be made of wrought-iron or mild-steel drop forgings welded (Shepherd's Patent), and to have bronze or gun-metal

bearings well fitted in. Each box to be held in position by two bolts $1\frac{1}{8}$ in. diameter and 10-in. centres.

Other approved axleboxes to suit the bogies adopted may be used.

The bearings to be roughly bored and then lined with approved anti-friction metal having a minimum thickness of $\frac{3}{16}$ in.

9. *Axles.*—Exactly as specified for 15-ton wagons.

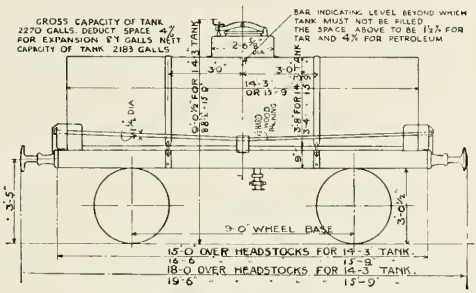

GROSS CAPACITY OF TANK 2270 GALLS. DEDUCT SPACE 4% FOR EXPANSION 87 GALLS NETT CAPACITY OF TANK 2183 GALLS
BAR INDICATING LEVEL BEYOND WHICH TANK MUST NOT BE FILLED THE SPACE ABOVE TO BE 1½% FOR TAR AND 4% FOR PETROLEUM
9'-0" WHEEL BASE
15'-0 OVER HEADSTOCKS FOR 14'-3 TANK.
18'-0 OVER HEADSTOCKS FOR 16'-3 TANK.

Fig. 117.—Private Owners' Standard 10- or 12-ton Rectangular Tank Wagon (side elevation)

Tank Wagons.—Private owners are permitted to have tank wagons built for the conveyance of liquids, but these are not numerous, and are principally used in the districts where chemicals are manufactured, and for the carriage of tar from gasworks to these manufacturers. As illustrations

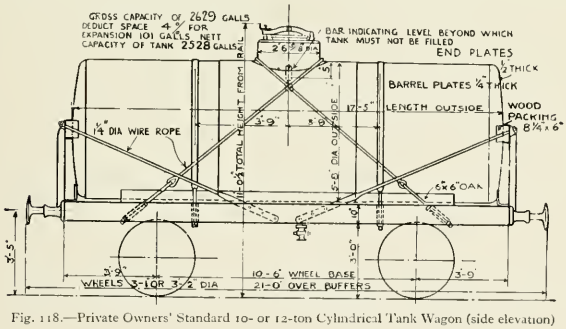

GROSS CAPACITY OF 2679 GALLS
DEDUCT SPACE 4% FOR EXPANSION 101 GALLS NETT
CAPACITY OF TANK 2528 GALLS
BAR INDICATING LEVEL BEYOND WHICH TANK MUST NOT BE FILLED
END PLATES
BARREL PLATES ¼" THICK
LENGTH OUTSIDE
WOOD PACKING
1" DIA WIRE ROPE
10-6" WHEEL BASE
21-0" OVER BUFFERS
WHEELS 3-1OR 3-2 DIA

Fig. 118.—Private Owners' Standard 10- or 12-ton Cylindrical Tank Wagon (side elevation)

of these vehicles, figs. 117, 118, 119 show three types, the first being a 10- or 12-ton rectangular tank, the second a 10- or 12-ton cylindrical tank, and the third a 20-ton cylindrical tank. As it would not be of general interest to give full drawings and specifications of these, notes are given under the diagrams of the principal points appertaining to each, and sufficient detail is embodied to give a general idea of the construction of the trucks. It

may be added that under no circumstances are wooden underframes permitted in the construction of tanks intended to convey inflammable liquids, and that such tanks when built have to be painted a light stone colour, with a bright-red band 6 in. wide running horizontally round the centre.

Starring of Tank Wagons.—Tank wagons—having the draw and buffing gear, wheels, axles, and wheel base in accordance with the latest standard specification, also oil axleboxes, and bearings lined with white metal—may be run on fast goods trains at an average speed of 35 miles per hour from point to point; the distance between stops to be limited to 40 miles. New tank wagons will not be accepted for this traffic until they have run 100 miles on slow trains, the owner or builder to furnish proof of this before the wagons are accepted for "starred" traffic.

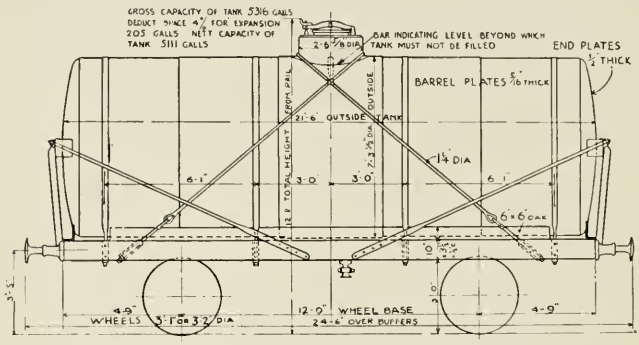


Fig. 119.—Private Owners' Standard 20-ton Tank Wagon (side elevation)

When the foregoing conditions have been complied with, the owner must paint upon each side of the tank at cross corners a star which must be black for white or yellow tanks, and white for other coloured tanks: whilst the railway company, which approved the starring, will affix to the underframe special plates showing their initials, the registered number of the wagon with the letter "A" affixed, and the month and year so dealt with.

Covered Goods Vans.—Covered goods trucks are mostly built and used by the railway companies themselves, being essential for the conveyance of dry and perishable goods. As these vehicles have frequently to run in passenger trains, many of them are equipped with a power brake (or brakes), carriage wheels, and long bearing springs, and have a wheel base suitable for travelling at high speeds. Such a vehicle is shown in fig. 120. As will be seen by reference to the illustration, it is equipped with portable shelves for carrying fruit at the proper season. Some companies construct these vehicles with top pair of hinged doors and a bottom flap, which latter can be opened on to a loading dock to facilitate loading and unloading operations. Ventilation is provided on the sides by a series

of holes bored through the casing and partially covered with sheet-iron plates; and two ventilators of the torpedo pattern are placed in the roof.

The underframe is of Stettin oak, and the 11-in.-by-$4\frac{1}{8}$-in. soles are plated with 11-in.-by-$\frac{3}{8}$-in. mild-steel plates. The draw gear is elastic and continuous, and the cradle is of the latest pattern, having both rubber and steel auxiliary springs. Similar trucks, fitted inside with bars and hooks, are also built for the conveyance of meat killed in this country, and sent up to London and other large towns by fast trains. In the vehicle illustrated the carrying capacity is marked at 8 tons, with a tare of about

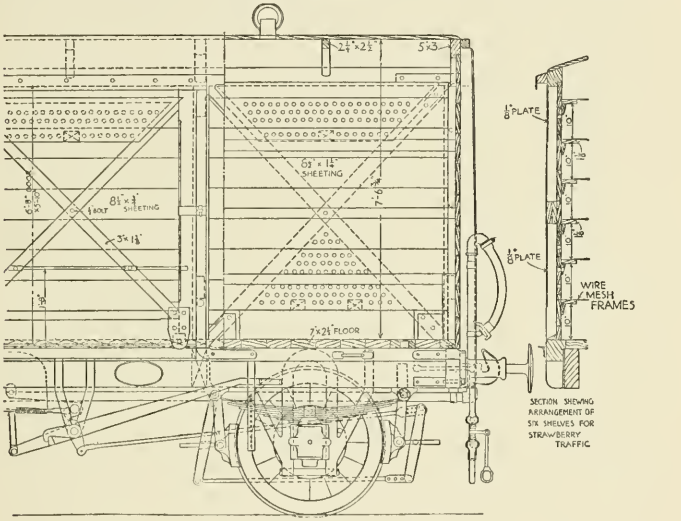


Fig. 120.—Ventilated Covered Goods Wagon

$8\frac{1}{4}$ tons; but when similar trucks are not required to travel with passenger trains, they are built with somewhat stronger frames, shorter springs, and wagon wheels, and carry a load of 10 tons.

Cattle Trucks.—Special vehicles are used on all railways for the conveyance of cattle. The charge made for the use of these is in proportion to the floor space occupied, and they are therefore so constructed that by means of a movable partition they may give "small", "medium", or "large" accommodation, as paid for, this accommodation being respectively 13 ft. 6 in., 15 ft. 6. in, and 18 ft. Very many devices, more or less successful, have been brought out to ensure that the partition shall not be surreptitiously moved during a journey; but the arrangement of a dovetail notch on the side rails was most generally used. To move the partition when once set, it was necessary not only to draw the bolts, but to raise

the partition to a considerable angle before the top bar could be lifted clear of the notch—an operation requiring considerable strength when the truck was empty, but becoming almost impossible when the vehicle was loaded if the attempt was made from the outside. However, whilst this arrangement possessed many advantages, it was found to be very difficult to load small animals behind the partition and larger ones in front thereof, and consequently on many lines these partitions are now made to drop into straight notches cut in top and bottom side rails at one end of the truck.

Much thought and care have been given in recent years to making the interior of these vehicles comfortable for the animals during transit. In recent military manœuvres these trucks have been found very useful for the conveyance of horses; and in order to give more head room in loading and unloading when used for this purpose, new vehicles are being constructed about 6 in. higher than formerly. To prevent infection, the trucks are thoroughly cleansed and limewashed after every journey in use.

The tare of the vehicle is approximately $7\frac{1}{2}$ tons, and marked to carry 8 tons.

Prize animals and valuable live stock, when conveyed by rail, are generally attended by a drover, and for this class of traffic specially designed vehicles are used. There is not the necessity for inspection space at floor level in these trucks as in the ordinary vehicles, the beasts being under constant observation by the attendant, who can also regulate the ventilation by opening an end sliding door, &c., as required. Some companies fit their special cattle trucks with a manger and water trough for feeding during transit, the water being carried in a tank fitted in the roof. Such trucks and many of the ordinary ones are equipped with power brakes, carriage wheels, and long bearing springs, making them suitable for travelling in passenger trains when required.

Board of Agriculture Rules—Special Vehicles.—In March, 1904, the following regulations were issued by the Board of Agriculture as to the construction of cattle trucks, horse boxes, &c.:

1. From and after the Thirty-first day of October, 1904, this Article shall be substituted for Article 7 of the Animals (Transit and General) Order of 1895.

2. No animal, horse, ass, or mule shall be carried by railway in a truck, horse box, or other vehicle, unless such truck, horse box, or vehicle is in accordance with the provisions of this Article.

3. Every truck, horse box, or other vehicle shall be provided at each end with spring buffers; and the floors thereof, in order to prevent slipping, shall, in the case of a truck used for the carriage of cattle, horses, asses, or mules, be fitted with battens or other proper footholds, and in any other case either be so fitted or be strewn with a proper quantity of litter or sand or other proper substance.

4. The battens in a truck shall be placed across the truck, except between the doorways, where they shall be placed lengthways.

5. Every truck shall be so constructed as to admit of ventilation and inspection at the floor level.

6. Every truck shall be so constructed that the interior thereof shall be free

from any boltheads, angles, or other projections likely to cause suffering to animals carried therein.

7. Every falling loading door and every gangway, passageway, loading or unloading board shall be fitted with longitudinal battens or other proper footholds.

8. Every truck built after the date of this Order shall be fitted with a roof and with falling loading doors of a pattern approved by the Board, and all internal projections shall be rounded.

9. Every truck or other vehicle shall be so constructed as to permit of its being effectually cleansed and disinfected in manner provided by the Animals (Transit and General) Order of 1895.

NOTE.—The above were subsequently confirmed and contained in General Order of 1912.

Boiler and Girder Wagons.—For the conveyance of heavy machinery, boilers, armour plate, bridgework, &c., it is necessary to have trucks with the floor line as near to the rail level as practicable, not only to keep the centre of gravity low, but to enable large articles when in position on the truck to be within the maximum loading gauge. There is a great variety of these trucks in use on the various railways, their carrying capacities ranging from about 12 to 50 tons. The solebars of long bogie wagons of high carrying capacity are usually of deep built-up girders with a suitable camber, put in when erected, as it is impossible to truss them for want of space below the frame. The designs of these special trucks vary considerably to suit the kind of traffic for which they are built, and it should be noted that no definite tare figure can be given in any way proportionate to the weight-carrying capacity. It should also be mentioned that 50 tons is not the maximum load that could be carried, as certain companies are prepared in emergency to provide vehicles in sets to carry a load up to 85 tons.

The conveyance of heavy guns during the recent Great War necessitated the construction of special vehicles for that purpose, and, as an example, it is of interest to record that sets of these (three) bogie wagons of tares about 17½ tons each with suitable superimposed girders gave a carrying capacity up to 130 tons.

One or two companies have built long boiler trucks with the buffing and draw gear fitted to the bogies instead of to the underframes, the main object being to facilitate the working of the vehicles on sharp curves. In this case the frame ends are suspended by strong links from the bogie centre, and, as all the buffing and draw stresses come upon the trucks, they have to be made very strong.

Timber Wagons.—The traffic in timber from the various seaports to inland towns is considerable in the form of logs, scantlings, deals, and battens, and special trucks are built and kept by the companies for this purpose. A fair proportion of this traffic is to the railway companies own works, and to contract shops for the building of rolling stock. Logs of oak, pitch pine, and pine, varying from about 40 to 70 ft. long, have to be conveyed by rail; and these are usually placed upon trucks similar to

that illustrated in fig. 121, the number of trucks used varying according to the length of log. These trucks are 13 ft. long over headstocks, and fitted with radial bolsters and screw couplings, the latter to enable them to be fairly closely coupled in transit. The draw gear, although it is continuous, is of a special character, the draw rubbers taking their bearing on the central bolster beams, and the draw bar having an elongated

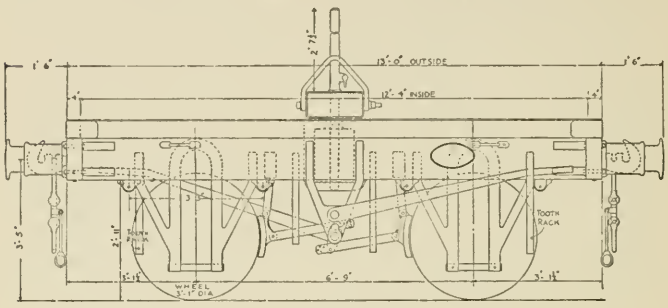


Fig. 121.—Timber Wagon

hole for the bolster centre pins to pass through. The shoulder of each draw hook is kept ½ in. from the headstock draw-bar plates, and the draw movement therefore is limited to this figure. The vehicles are equipped with suitable binding chains, shackles, and stanchions for adequately securing the load, and each wagon is designed to carry 10 tons. The tare is 5 tons. Some companies run twin timber trucks (four-wheelers),

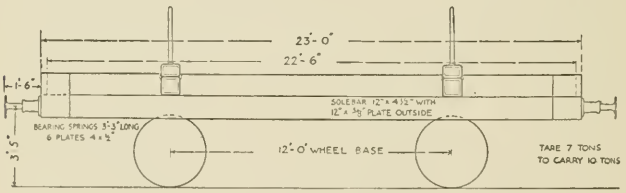


Fig. 122.—Batten Wagon

the extreme ends of which are fitted with ordinary buffers and draw gear; but the inner headstocks have radial faces, with a central slot, through which draw bars work somewhat on the " scissor " principle.

The practice of conveying long logs on a number of short trucks is not to be commended, and is gradually being superseded by the introduction of bogie timber trucks, somewhat of the type of the rail wagon shown in fig. 123; and when the logs are so long as to oversail the wagon at both ends. short runner trucks are used.

For the conveyance of battens and deals, which seldom exceed a length of 23 ft., trucks with two fixed bolsters are used, and a diagram of this type is shown in fig. 122. As the wheel base does not exceed 12 ft., it is possible to turn these trucks on the average turntable, a great convenience in wharves and shunting yards. The overhang from the wheel to the end (5 ft. 6 in.) being more than usual, the buffing spring in this case is not carried directly behind the headstock, but some 3 ft. nearer the wheel, so that the weight thereof will not have a tendency to "hog-back" the frame. These wagons have a carrying capacity of 10 tons, with an average tare of 7 tons.

Rail Trucks and Ballast Wagons.—The introduction of longer (45 ft.) and heavier (90 lb. to the yard) steel rails for use on the main lines of permanent way gave rise to the necessity of a suitable truck to carry them. The vehicle shown in fig. 123 was specially designed for this work, and is typical of similar trucks on most lines. It is 47 ft. 6 in. long over the headstocks, carried on two diamond-framed bogies 34 ft. 6 in. apart. The soles and middle longitudes are of mild steel of girder section 10 in. by $4\frac{1}{2}$ in., weighing 30 lb. per foot, all four being adequately trussed with $1\frac{3}{8}$-in.-diameter rods. It has four fixed bolsters with movable stanchions, all fitted with D shackles, chains, and binding screws for securing the load. The journals are 10 in. by 5 in., with oil axle-boxes, and the axles $6\frac{3}{4}$ in. diameter at the wheel seat and 6 in. diameter at the centre. The average tare of these trucks is $17\frac{1}{2}$ tons, with a carrying capacity of 40 tons.

Special trains for ballasting purposes are now in use on many lines, since they not only save considerable time compared with the old method of hand labour by navvies, but are a great convenience from a traffic point of view, enabling the ballasting to be done with little interruption of the ordinary working of the line. These trains consist of a number of ballast hopper wagons with a plough van at each end. The discharging gear of the wagons is worked by a screw and hand wheel, and can be so regulated as to deliver

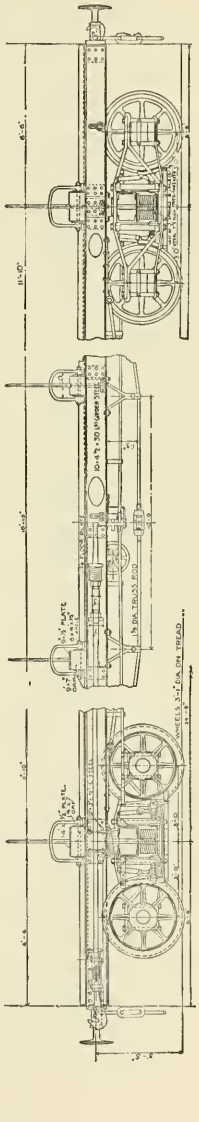


Fig. 123.—Rail Wagon to carry 40 tons

the requisite quantity of ballast to suit the speed (about walking pace) of the train when at work. When the spreader on the plough is lowered, it carries out the levelling required. In wet weather, should any of the ballast hold up on the inclined ends of the wagons, steps and hand rails have been provided to enable a man to clear the material away. These wagons have capacities up to 40 tons.

The London and South-Western Company's hopper trucks are 32 ft. long over headstocks, and have a capacity of about 32 c. yd., with a tare of about 17¼ tons. Smaller trucks with a capacity of 9⅓ c. yd. (equivalent to about 12 tons) are also used for this work. The plough van is 20 ft. long over headstocks, with a wheel base of 13 ft., and also answers the ordinary purposes of a brake van. The underframe is of steel, with channel solebars 12 in. by 3 in. by ⅜ in. It has laminated buffing and draw gear, but the latter is not continuous, owing to the position of the mechanism in connection with the lifting gear of the spreader. The latter is stiffened with ¼-in. plate and 2½-in.-by-2½-in.-by-⅜-in. angles, and the stress, when in use, is taken up on a 3½-in.-diameter pin and a suitable casting, together with stay guides at the back. Hopper wagons are sometimes fitted complete with the vacuum brake, but the plough vans have pipes only with the standard van valve and gauge.

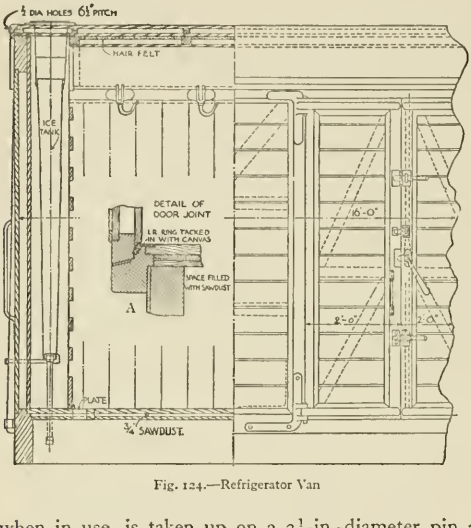


Fig. 124.—Refrigerator Van

Meat-traffic Vans.—Refrigerator vans are chiefly used for the conveyance of frozen meat from the seaports to the large towns, and the considerable increase in this traffic of recent years has made it necessary for those railway companies upon whose lines the ports are situated to largely augment their stock of these vehicles. A section of the body of an average British van is shown in fig. 124; and although the arrangement is not so elaborate as that adopted in American cars, it must be borne in mind that distances travelled in Great Britain do not call for the meat to be more than a day or two at most in the vans. The vehicle illustrated is 16 ft. long over headstocks and 7 ft. 1½ in. width inside, with a length of about

13 ft. 8 in. clear inside. The sides and ends of the vehicle are double cased, the intervening space being filled in with silicate of cotton, while thick " Genasco " two-ply paper covers the inside casings. The roof is triple cased, and consists of: (1) a $\frac{7}{8}$-in. outside casing covered with roof canvas painted, (2) a $1\frac{1}{4}$-in. air space with $\frac{5}{8}$-in.-diameter holes leading in every direction to give a current of air when travelling, (3) a $\frac{3}{4}$-in. casing covered with about $\frac{1}{2}$ in. of hair felt, (4) another air space of $1\frac{1}{2}$ in., and (5) finally a $\frac{9}{16}$-in. casing. The floor is double cased, with $\frac{3}{4}$ in. of fine sawdust rammed tightly between. The joints of the door are sealed with rubber and canvas (see detail at A in fig. 124), and two tanks to receive ice are fixed one at each end of the vehicle. The interior of these vans is varnished; and although zinc has been extensively used for lining refrigerator cars, it has been found that under certain conditions of the atmosphere the sweating which takes place congeals on the zinc, and is not so conducive to keeping the inside " sweet " as when varnished boards are used. The method of insulation varies somewhat on the different lines, some companies using hair felt exclusively, and triple-casing the vehicles all over. The underframing of these vehicles is of similar construction to that shown in fig. 120. As they are fitted with power brakes, &c., these vans are enabled to travel in fast trains whenever required. They are painted a light stone colour so as not to absorb the heat. The tare is $9\frac{1}{4}$ tons, and they carry a load of 8 tons.

In connection with meat traffic, it may be mentioned that large quantities of meat are conveyed to London in road vans loaded upon trucks suitably designed for the work; and in this way much time and labour is saved at the railway terminus, all that is necessary for speedy delivery at the market being to run the vans off the truck and attach a pair of horses to each. Such trucks have a tare of $7\frac{3}{4}$ tons and will carry 12 tons. The road vans average in weight 34 cwt., and carry about 4 tons each.

Standardization of Wagons and Details.—During the last few years there has grown up a strong opinion that considerable economy in maintenance of wagon stock would be effected if all new wagons were built to standard types, and the main details, such as wheels, springs, axle-boxes, buffers, draw gear, and brakework all interchangeable. This opinion is no doubt, in a great measure, due to the delays and inconvenience experienced during the War in repairing damaged and crippled wagons, and this difficulty was mostly found in dealing with trucks belonging to the various railway companies. It is well known that the variety of the fittings on these wagons is very large indeed, and although to facilitate repairs under the common-user arrangements each company supplied to others at certain places a stock of spare parts for immediate use, this precaution did not prevent many serious delays. Under a rigid and compulsory system of standardization in building new trucks, this multiplicity of variation in details would gradually pass away in the next two decades as the stock became worn out and scrapped. However, the argument frequently heard against this proposal is certainly one which cannot be ignored, namely,

that such standardization would ultimately mean stagnation in progress and retardation in improvement. In all probability much could be effected by a reasonable middle course which should admit of the adoption at any time of improvements, which undoubtedly lessened the probability of breakdowns and damage to wagons, and which would thereby facilitate transport. The problem is a difficult and complicated one, and very naturally the representatives of the owners of private wagons (who have since 1887 been compelled to build to Railway Clearing-House specifications) demur to a new type of wagon being laid down unless all railway companies agree themselves to conform thereto. This to some companies would mean very heavy loss in having to scrap equipment details thus made obsolete but not yet worn out, and this proposed change coming at a time when the greatest need for economy exists to enable railways to pay their way, it is easy to understand why the matter is still unsettled and being further considered.

Briefly, the proposal at present is to have a 12-ton standard mineral wagon and a 12-ton standard merchandise and coke wagon, the former being 16 ft. 6 in. long over headstocks, 8 ft. 6 in. wide over all, and 4 ft. 4½ in. depth inside, and the latter 17 ft. 6 in. long over headstocks, with width and depth to suit the kind of traffic they are intended for. It will be permissible to build the underframes of oak or other approved timber, or of wrought-iron or mild-steel sections, and the principal details will no doubt be retained as nearly as possible to those laid down in previous specifications.

It was hoped to have been able to include in this article full particulars and drawings of the new standards, but as a final settlement has not yet been arrived at, no good purpose would be served in anticipating the ultimate results and decisions. Presumably, if the 12-ton standard wagons are found satisfactory other specifications will from time to time be issued for standard trucks of higher capacity, but, for obvious reasons, their adoption in this country must of necessity be a matter of some considerable time.

Guards' Vans for Goods Trains.—Goods trains are heavier and longer than they were a few years ago, and the guards' vans for use with them have necessarily been increased in weight and equipped with very powerful screw hand brakes for use on inclines. The standard van formerly weighed about 10 or 12 tons, but vans from 20 to 25 tons are now the general practice. A modern 20-ton van used on the London and South-Western Railway may be taken for description, and is illustrated in fig. 125. The body is divided into four parts, viz. two verandas, enabling the guard to get in at either end; one transhipment compartment for road box traffic, &c., and one guards' compartment, the latter being equipped with a stove and hand-brake wheel within easy reach of the seat. The van has side lookouts similar to passenger coaches, and other windows suitably placed so that the guard may see out in either direction. This van is 18 ft. long over headstocks, with a wheel base of 10 ft. 6 in., and the body framing is constructed of Stettin oak with casings of deal. The outside panels of

the side lookouts are of mahogany and the wing pillars of teak. The underframe is entirely constructed of black butt (which weighs about 60 lb. per cubic foot as against about 50 lb. for oak), and all available space is converted into " pockets " to receive small scrap iron, &c., for weighting purposes. Between the top of the underframe and the $1\frac{1}{4}$-in. oak floor-boards there are placed transversely castings 3 in. thick, 7 in. wide, and 6 ft. 10 in. long, and in this position the weight is well distributed over the frame. All the framing is 12 in. deep, with soles 12 in. by 5 in., strengthened with $\frac{1}{2}$-in. steel plates. The wheels are of the standard

Fig. 125.—20-ton Goods Brake Van

diameter for wagons, viz. 3 ft. 1 in., but the axles have 10-in.-by-5-in. journals, with wheel seats $6\frac{3}{4}$ in. in diameter, and are 6 in. in diameter at the centre. The theoretical hand-brake power of the brake in this vehicle is $88\frac{1}{2}$ to 1. As might be expected, the tare of these vans varies somewhat, the actual tare of the vehicle under description being 20 tons, 9 cwt. 3 qr. Some companies build these vans with frames entirely of steel, and slightly longer than the example described; in which case, as there is more room for the weighting scrap, the castings under the floor may be dispensed with.

Carriage Trucks.—The great increase in the use of motor-cars has considerably curtailed the use of open and covered carriage trucks on British railways. Many of these vehicles, which were built expressly for the conveyance of private carriages, are now more frequently used for carrying scenery, furniture vans, &c., but the longer covered trucks during

the European War proved very useful for the transit of parts of aeroplanes. The covered vehicles, when suitably ventilated, are often used for milk

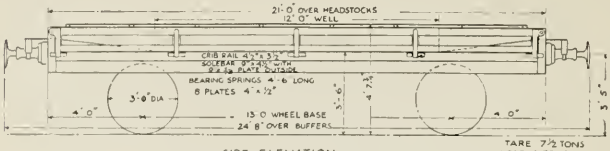


Diagram of 21-ft. Well-floor Open Carriage Truck

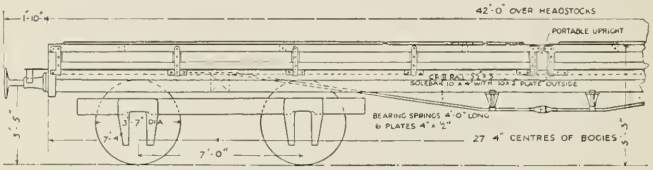


Fig. 126.—Diagram of 42-ft. Bogie Open Carriage Truck

traffic. Fig. 126 gives diagrams of open trucks, the first being a 21-ft. well-floor vehicle, and the second a 42-ft. bogie truck. The former vehicle

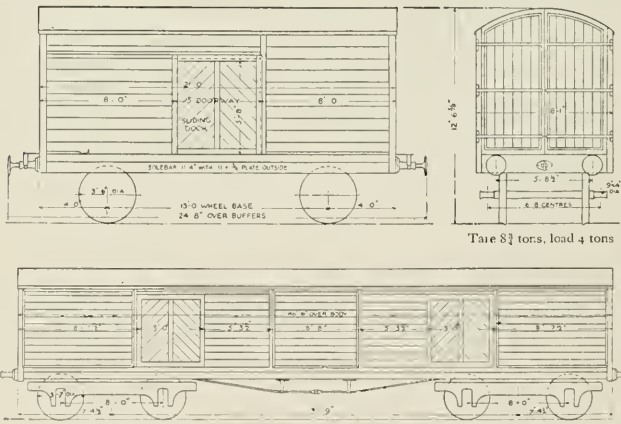


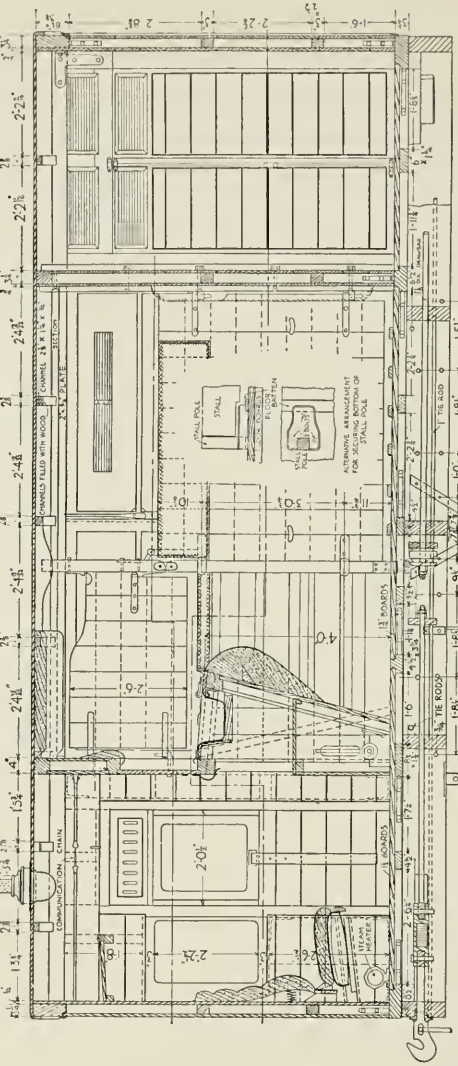
Fig. 127.—Diagrams of 21-ft. and 46-ft.-6-in. Covered Carriage Trucks

has ramp ends, with a 12-ft. well 3 ft. 6 in. from rail level, thus enabling a road vehicle of exceptional height to be safely conveyed. The tare of this truck is $7\frac{1}{2}$ tons, and is designed to carry a load of 6 tons. The bogie

truck was more particularly designed for carrying theatrical scenery, but is capable of conveying three carriages if necessary. It is carried on two four-wheeled bogies 27 ft. 4 in. apart, the bogies themselves having a wheel base of 7 ft. The sides are of the drop pattern to facilitate side loading from a platform, and the truck is fitted with movable wheel bars, wheel plates, &c. The tare of this vehicle is 16¼ tons, with a weight-carrying capacity of 10 tons.

Two diagrams of modern covered carriage trucks are shown in fig. 127, one being a four-wheeled vehicle 21 ft. long, with a wheel base of 13 ft., and the other a bogie vehicle 46 ft. 6 in. long with bogie centres 31 ft. 9 in. apart; the latter being sufficiently long to convey the maximum size of theatrical scenery. Both vehicles are fitted with sliding doors at the side and hinged doors at the ends, and are 8 ft. 1 in. wide over body; but the bogie vehicle is about 1 ft. less in height, being built for through traffic and to pass the smallest loading gauge in Britain. The tares and loads of these vehicles are shown in the drawings. The trucks are fitted with Westinghouse and vacuum brakes complete, and through steam pipes, the latter to enable them to be placed in any part of a passenger train when required.

Horse Boxes.—Notwithstanding the rapid development of the motor-car industry, horse boxes are quite as much in requisition as formerly, and considerable improvement has taken place in recent years in the construction of these with the view of giving as much comfort as possible both to the horse and the attendant. The standard length for these vehicles was formerly about 16 ft. with a wheel base of 9 ft., but the riding of such vehicles on the end of a fast train was not all that could be desired, and modern practice is to build the boxes about 21 ft. long over the body with a wheel base of at least 13 ft. The body of such a vehicle is shown in fig. 128, and the underframe for this box was described and illustrated in the early part of the chapter on underframes (p. 98). The body is divided into three parts, viz. an attendant's compartment 4 ft. 10½ in. long, one horse compartment (to take three horses) 10 ft. 1½ in. long, and a luggage compartment 4 ft. 8 in. long, the latter being used to place the partition stalls in when not in use, as in the case when the vehicle is used as a loose box. The main framework of the body is of oak and teak, and the parts which are panelled are of ⅜-in. mahogany, the bottom flap being made of 1¾-in. deal. A powerful spring cased in under the manger controls the flap when being let down, and this not only tends to prevent a restive horse from being frightened by the bang of the flap on the platform, but saves much damage to the flap itself. Most horse boxes have the manger pans open; but owing to the extraordinary fact that horses, although securely tethered, will occasionally get their fore feet in these, with serious results to themselves, some boxes have recently been equipped with strong iron sliding lids to the mangers, the object being that the horse would suffer much less injury by forcing through the back wooden flap than in kicking through a cast-iron pan. The attendant's compartment is



Longitudinal Section

Fig. 128.—21-ft. Horse Box

gas-lighted and steam-heated, and the vehicle is fitted with dual power brakes, side hand brake, and passenger communication. The tare of this horse box is 9 tons 13 cwt.

CHAPTER XI

Horse-drawn Road Vehicles

Although part of the collection and delivery of goods in the towns is usually done by agents of the companies, a large portion is carried out by the railways themselves; and for this purpose they require a considerable stock of road vehicles. The building and maintenance of these form a part of the carriage and wagon department's work. The types of these vehicles vary considerably in different parts of the country, not only to suit the class of traffic, sizes and weights of loads, &c., but to be suitable for the district in which they are required to work. It will be readily understood that vehicles suitable for a flat district would often be of little use in a very hilly town, and that the flat-bottomed cotton lorries of the north of England would not be serviceable for much of the traffic in the south. Both horse-drawn and mechanically propelled vehicles are used for this work, and in order to illustrate average practice in the building of the former the writer gives in Plate IX a working drawing of a three-horse van designed to carry 6 tons; and proposes to describe

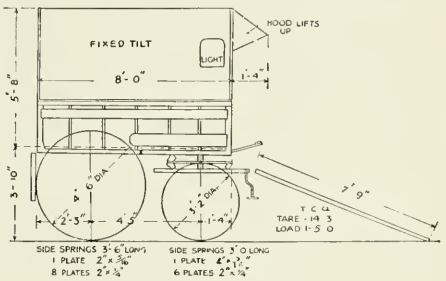
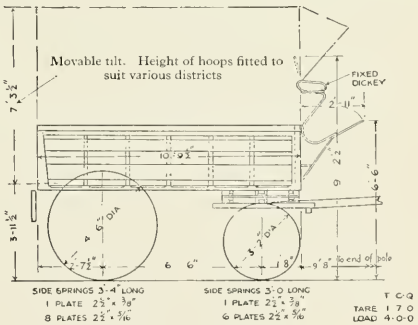


Fig. 129.—One-horse Parcel Van



SIDE ELEVATION

Fig. 130.—Pair-horse Van

the workshop practice in building this van. The latter is, with little modification, similar in all vans, and will convey to the reader the general principles of the work.

To illustrate some of the principal types of vehicles in use several diagrams are given, that shown in fig. 129 being a one-horse parcel van to carry $1\frac{1}{4}$ tons with a tare of 14 cwt. 3 qr. Fig. 130 shows a heavy pair-

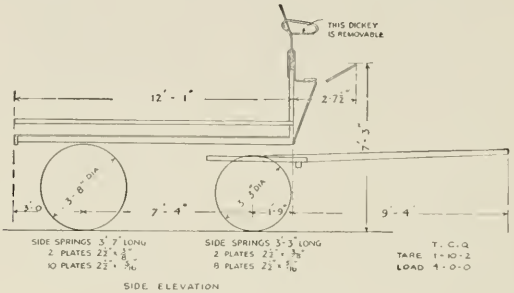


Fig. 131.—Pair-horse Trolley

horse van with sides suitable for the conveyance of mixed goods, and has a carrying capacity of 4 tons, with a tare of 1 ton 7 cwt. A one-horse van designed to carry half the load of the preceding van has a tare of about 19 cwt. A pair-horse trolley (or lorry) is shown in fig. 131; this carries 4 tons, with a tare of 1 ton $10\frac{1}{2}$ cwt.

In large towns the conveyance of crates of glass of large dimensions

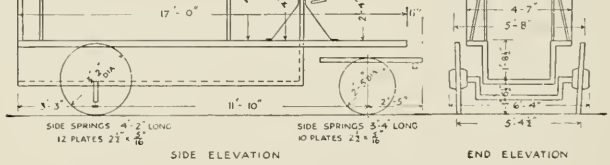
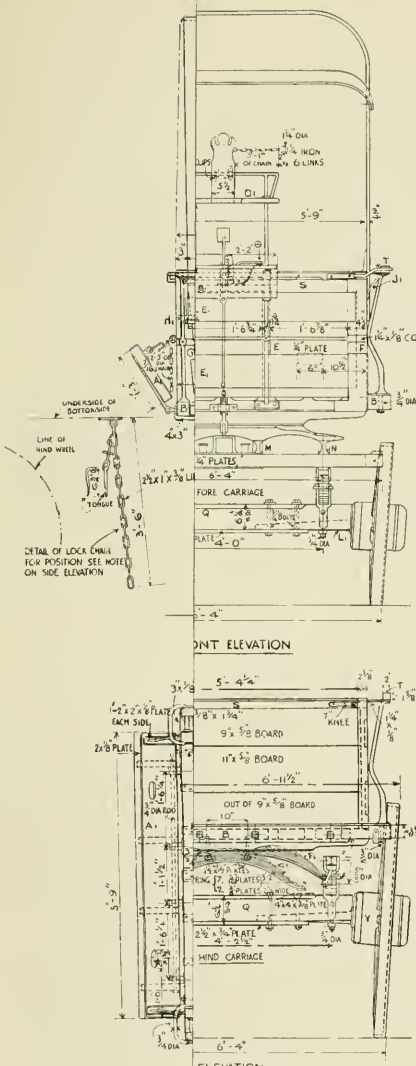


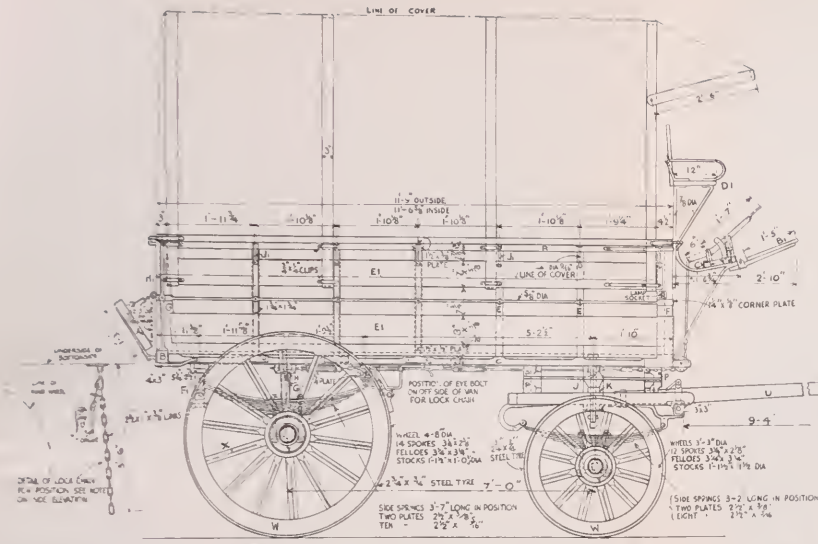
Fig. 132.—Pair-horse Glass Crate Trolley

requires special vehicles, and fig. 132 shows the outline of a suitable trolley for this work. It will carry 4 tons, and has a tare of 1 ton $8\frac{3}{4}$ cwt. A very useful vehicle for the conveyance of pianos, small crates of glass, cattle, and heavy items, which it is not desirable to lift high above the ground, is what is technically known as a "float", and this is illustrated in fig. 133. It will carry a load of 4 tons, and has a tare of about 1 ton 8 cwt.



INDICATING LETTER	TECHNICAL NAMES FOR THE PARTS INDICATED	MATERIAL
A	FRONT EARBORD	ENGLISH OAK
B	HIND EARBORD	" "
C	BOTTOM SIDES	" "
D	SUMMERS	" "
E	STANDARDS	" "
F	FRONT PILLARS	" "
G	HIND PILLARS	" "
H	SPRING BARS	ENGLISH ASH
J	BODY BOLSTER BAR	" "
K	TOP " "	" "
L	BOTTOM " "	" "
M	MIDDLE GUIDES	" "
N	OUTSIDE "	" "
O	SPLINTER BAR	" "
P	SWEEP PIECES	" "
Q	AXLE BED	" "
R	BODY RAVE	" "
S	HEAD "	" "
T	FLOATING RAVE	" "
U	CENTRE POLE	" "
V	BACK BAR	" "
W	FELLOES	" "
X	SPOKES	ENGLISH OAK
Y	STOCK NAVE OR HUB	" "
Z	LINING BOARDS	RED DEAL
A1	TAIL BOARD	ELM
B1	FOOT "	"
C1	HEEL "	"
D1	SEAT "	"
E1	FASCIA BOARD	BIRCH
F1	DUMB JACK SPRING	STEEL
G1	CHECK SPRING	"
H1	IRON SHORE STAFF	WROT IRON
J1	RAVE STAYS	"
K1	CROSS "	"
L1	AXLE ARM	"

[*Facing p. 246, Vol. I*


LINE OF COVER
11'-3" OUTSIDE
11'-0⅜" INSIDE
1'-10⅜"
1'-10⅜"
1'-10⅜"
1'-10⅜"
1'-9¾"
1'-11¾"
1'-10⅜"
5'-2"
5'-2"
5'-2

Building of Three-horse Vans (see Plate IX)—**Frame and Body.**—The timber (in plank) is cut to rough sizes by circular saws, and, after passing through the facing or thicknessing machines as required, it is set out by the wheelwright to the drawing and standard templates. The bolsters and sweeps are cut out at the band saw. All mortices, tenons, holes, &c., having been marked, the material is dealt with at the various machines and returned to the wheelwright, who then cleans out the mortices, &c., and does the necessary handwork. The frame is put together on trestles, the bottom sides, middle, and intermediate summers being driven into the front earbred and the hind earbred driven on to them, all joints being well white leaded. After the frame has been taken out of winding and squared, the tenons are pinned into earbreds with oak pins, the bottom sides being secured to earbreds by strapbolts. The front and hind pillars, side and front standards, and front and side body

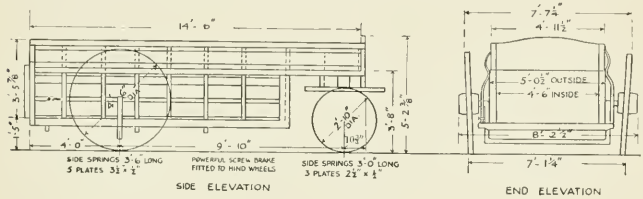


Fig. 133.—Float

raves are now fixed in and secured with pins, strapbolts, and plates, the fascia boards fastened in position, and the $\frac{5}{8}$-in. deal casing or lining boards fitted. The necessary plates for securing the joints are firmly bolted on and the iron shore staffs fixed through the ends of the hind earbred and bolted to centre of the hind pillars and floating raves. When the corner irons, cappings, cross stays, rave stays, &c., have been fixed in their respective positions, and the floorboards temporarily fitted, the body is turned over to have the bolsters, sweeps, and spring bars put on The bolster, which has the main pin plate and wheel plate fitted thereto, is securely bolted across the body. Eyebolts for side springs are fixed on front springbar, the cross or check spring placed in position on the middle springbar, and the two dumbjack springs attached to the end springbar. The body, being so far completed, now has the iron brackets attached to receive the cross levers for the double foot brake, and all bolts carefully cut off and filed and all joints cleaned off. The body may now be returned to its normal position, and the floorboards, which had been previously temporarily fitted, nailed down. It will be seen from the drawing that the free end of the side springs is attached by D shackles to the ends of the dumbjack springs, and that the cross spring acts as an auxiliary to the side springs when the latter have taken a proportion of the load.

Hind Carriage.—The hind axle bed, which should be of the best

English quartered ash, is faced and squared and carefully marked out and machined to receive the axle arms, which are bolted by four $\frac{3}{4}$-in. bolts (two to each) passing through the bed, arms, and bed plate where shown on the drawing. At the outer ends nearest the wheels the arms are secured by spring fasteners and couplings, the top part of fasteners being used to secure the springs to the bed. The arms being in their place and having the required pitch to suit the dish of the wheel, the springs may then be slightly let into the top of the bed and squared, then bolted by couplings on fasteners. This part, which is technically called the hind carriage, is now ready to be placed in position, and is attached to the body by $\frac{7}{16}$-in. bolts passing through the D shackles and front springbar eyebolts. Care should be taken that sufficient draught is allowed in coupling to the D shackles to admit of the body hanging level and to bring the cross spring over the centre of the axle line when the vehicle is loaded.

Fore Carriage—Brake Work.—The front carriage framework (composed of four guides, back bar, front or splinter bar, top and bottom bolster, and two sweeps), all of the best English ash, is now put together and securely fastened by bolts. The top bolster has a plate let in on the top, flush and central, for the main pin to pass through. This pin forms the centre for the front carriage to turn on. The sweep pieces have short iron plates bolted on top, both being made to the same radius as the wheel plate on body. The front and back scroll irons are now fastened on to the outside guides to secure the two front side springs; the front scrolls being also attached to the splinter bar and receiving the fixed ends of the springs. The back scrolls receive the free ends of the springs between drop shackles, and $\frac{5}{16}$-in. bolts are used at both ends of the springs. The axle bed, axle arms, and springs are fitted in the same manner as described for the hind carriage, the set of the arm being slightly less in the fore carriage, owing to the smaller diameter of the wheel having less dish. Stay irons are fixed on each side of the fore carriage, one end by a bolt through the splinter bar, the other end by a bolt through the outside guide. Two roller bolts are now fitted in the middle, and a trace chain casting at each end of the splinter bar. These are for attaching the horse trace chains, and there are also attached to this bar a pole lock and iron loop. The latter, having chains about 2 ft. long and secured to the central roller bolts, prevents the pole (when the loop is passed over the pole and the pole stop fixed at the back end and the pole chains at the front end) from being surreptitiously removed from the pole lock or lost. This arrangement, however, permits of the pole being removed when necessary, as, the chains being just long enough to admit of its being drawn out of the sockets, the pole can then be pushed through the loop and laid on the ground under the van. A back pole socket is fixed under the two middle guides to retain the back end of the pole.

The van is fitted with a powerful foot brake. The actuating lever, supported by brackets on the heel board, is connected by a system of a chain and rods to the transverse levers attached to the bottom sides, and one end of each of these levers carries iron blocks adjacent to the wheels.

The other end of the transverse levers is connected by chains to an adjusting shackle and screw, which in turn is attached to a plate or coil spring for release purposes. When the brake is applied a tooth on the foot lever engages with a notched rack, which, being centred at the bottom, can be released when the driver places his foot on part marked thus ⊕. The arrangement of this gear is clearly shown on the drawing.

Wheels.—The wheels should be made of the very best quality of timber, thoroughly seasoned. The hubs (or stocks) are of English oak butts (i.e. the first cut off the trunk after the tree has been felled) and the spokes of English cleft oak, all free from sap, shakes, and knots. The felloes are of English ash, and the dowels and wedges of dry English oak. The hubs are cut to a rough size at the circular saw and then turned in the lathe to the required diameter and length, two lines $\frac{1}{2}$ in. apart being made around the circumference showing face line for spokes. These lines denote the position of the spokes alternately, which, in workshop parlance, are known as " offs " and " ons ". The hubs are now carefully marked out for mortises to receive the tenons of the spokes (fourteen for hind hub and twelve for front), and these mortises are cut by a suitable machine. The hoops are now shrunk on the hubs by the blacksmith to prevent splitting when the spokes are being driven in. The spokes, having been shaped, cut to length, and prepared by the various machines, are ready to be driven into the hub, which is usually done by sledge hammer over a wheel pit, the hub being firmly held in position by special irons and wedges. A face stock guage is used in this operation to ensure that all spokes are correctly fitted and show up perfectly true all round. Where a special hydraulic press, known as a tyre-setting machine, is available for this work, its use is preferable, as also for placing the felloes on to the spokes, as it ensures that there shall be no damage to the parts from the blows of the sledges, which may occur unless great care is taken. Again, by using hydraulic pressure the parts are so firmly put together that, in hooping, the tyre does not require to be made so hot to give a solid finished wheel. After the spokes are fitted the centre passes to a special machine for tanging and tenoning the spokes, when it is ready to have the felloes driven or pressed on. The felloes are dealt with at a special shaping machine, and are afterwards bored for dowels and mortised where required. A 3-in.-by-$\frac{3}{4}$-in. oak dowel is driven about halfway in one end of each felloe; and when the felloes have been fixed on equally all round, and the dowels are well in their places, the spoke ends, which are cut off $\frac{1}{2}$ in. shorter than depth of the felloe, are then wedged across the grain to bring them all tightly into position. The felloes now form a ring, but all joints should not as yet be close together, a little wedge-shaped space being left at each joint in order that, as contraction takes place when the tyre is put on, these joints may close up, thereby forcing the spokes into the hubs and the felloes on to the spokes. The wheel is now ready to be thoroughly cleaned off and given a priming coat of paint preparatory to tiring. It should be noted that the joints of the wheels receive no paint when being put together. The

tyre (say for the hind wheel) is made from a mild-steel bar 15 ft. by $2\frac{3}{4}$ in. by $\frac{3}{4}$ in., one edge of which is rounded, and when bent to the required diameter in the bending machine is shut up by the smith about $1\frac{1}{2}$ in. less in circumference than the wooden centre. The tyre is now drilled for the nails which will retain it in its place on the felloes, and afterwards heated in a special furnace (either vertical or horizontal) ready to be placed on the wood centre. The latter has in the meantime been placed and secured face downward on the sinking platform, and in such a way that the tyre, when put on, will project about $\frac{1}{4}$ in. over the face of the wheel. This is done to protect the felloes from wear when drawing alongside kerbstones. When the tyre is adequately heated it is brought out and placed over the centre and gently hammered all round to its proper position, when the whole is lowered into the water for cooling out. When cold, the tyre may be nailed on, and the box fitted to the hub, the latter operation being usually done, after preparing the hole, by driving in with a sledge, oak wedges being finally driven in, from back and front, to firmly secure the box. What is technically known as a wheel-boxing gauge is used at this stage of the work, to ensure that the box is truly and centrally fitted. The front end of the hub is fitted with a lining hoop of sufficient size to permit a spanner or cap wrench being used in putting on the cap, or taking off when necessary. The wheel is now well cleaned, particularly round the felloes, so that, when painted, the paint may properly adhere to the woodwork. It should be noted particularly that in no case should the dowels in the felloes touch the bottom of the holes bored to receive them; because not only would it possibly prevent the joints being quite close up when the wheel is new, but when repairs are required, and a loose tyre has to be cut and shut, a piece must be cut out of one or two of the felloes to make them shorter (called jointing), and the dowels should still have room left to go slightly farther in without becoming bound. In a similar manner this applies to the tongues (or tenons) of the spokes, and necessitates their being cut back, or shortened, when rejointing, as, if this was not done, the tyre in contracting would press on the ends of the spokes and not tighten the felloes. It will be understood, therefore, that to get a perfectly sound finished wheel it must be free from the defects known as " dowel bound ", " felloe or ring bound ", and " spoke bound ".

Several railway companies have introduced various types of metal wheel stocks or hubs which are claimed to be stronger and less expensive to maintain than those of wood, and an illustration of one very good type in cast iron is shown in fig. 134.

Springs.—The steel for the seven springs is cut from the bars by shears to the lengths and number required, care being taken to make allowance for the drawing down at the ends of the plates, in this case $1\frac{1}{4}$ in., i.e. $\frac{5}{8}$ in. for each end. The ends are then brought to a red heat and drawn down, and, whilst still hot, are cut off square in a tool on the anvil or in a machine. They now pass to the punching machine for slotting, all being done to a gauge, the punch and bolster being regulated to suit length and

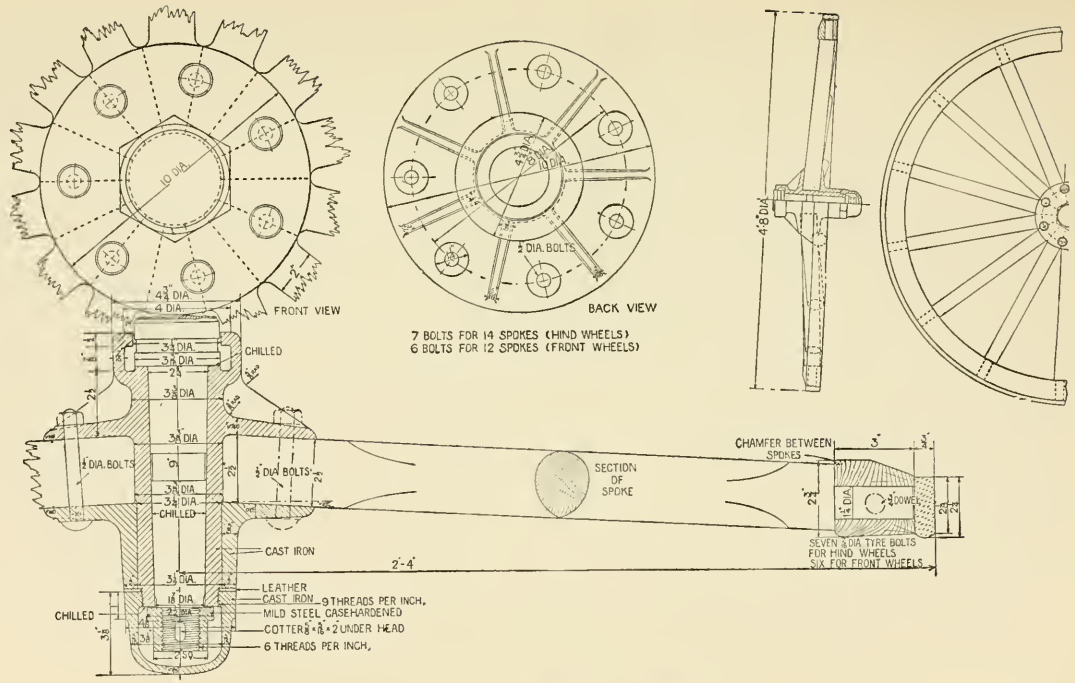


Fig. 134.—Cast-iron Centre for Single-horse Road Vehicle Wheel

width of slot required. All plates having been dealt with at one end, the operation is repeated, generally commencing with the shorter plates and working up to the longest. The back plate is, of course, not drawn down, but has an eye formed at each end to take the $\frac{9}{16}$-in.-diameter bolt when in position. All plates are marked and drilled at the centre to receive a $\frac{7}{16}$-in.-diameter bolt, and placed together so that the correct position for the nibs, to suit slots, may be determined; and the nibs or studs are formed by a punching plate on a bolster on the anvil or by machine. The plates are now marked with chalk and placed side by side as they will be when in the finished spring, and then, one by one, beginning with the longest plate, placed in a special furnace and heated, and afterwards bent to the required curve, care being taken that the ends of each touch the adjoining plate but are slightly off at the centre, to ensure that when finally bolted together they will bear their whole length. They are again heated in the furnace, and afterwards dropped into a trough of water or oil, and then given a certain amount of heat, as judged by the expert springmaker, for the purpose of tempering, and allowed to cool. Each plate is thoroughly cleaned before painting, to prevent rust; and when bolted together the spring is ready for fixing on the van. It may be noted that some companies prefer using boiled oil to prevent rust, instead of paint. The cross spring and dumbjack springs are let into their respective bars and secured in position by bolts and couplings. Full particulars of the springs are given on the drawing.

Ironwork—Wheel-locking Chain.—All the general ironwork is made to pattern or drawings by the blacksmith, and passes to the fitters' bench, where it is cleaned up and set out for drilling, turning, &c., as required. After being dealt with at the various machines it is ready for fixing in the required position by the wheelwright.

The wheel-locking chain is attached to the body by an eyebolt, and hangs down in front of the hind wheel when not in use (see drawing). When required (to prevent horses from moving the van when it is unattended) it is passed between the spokes of the hind wheel from behind, brought to the front, and passed around the felloes and tyre. The tongue is then passed through one of the links in such a way that the point lies alongside and close to one side of the buckle (the one having a ring on), and the ring is then slid up until it passes over the tongue, when it is dropped down, thus retaining the link of the chain, and securing the wheel.

Tilt or Cover—Driver's Dickey—Painting.—In this van the tilt is portable, and can be taken down when not required. The sheet, in position, is supported by four light hoops of rectangular section, and made of English ash or American birch bent to the shape required. These hoops are carried in staples, or sockets, on the side, as will be seen on the drawing, and when the cover is not in use all four hoops may be brought together and placed in the wide socket at the front, leaving the back clear for a high load.

The dickey irons, which support the foot, heel, and seat boards, &c., are firmly secured to the frame of the van where shown on the drawing,

and to these irons are fastened the driver's safety chains and board, the former being passed around the driver's waist to prevent him from being thrown off in case of accident. It will be seen that the dickey is so situated as not to project into the body of the van or to interfere with the loading space.

Brief particulars of the painting of this van are given at the end of the part dealing with that branch of work (see p. 184).

CHAPTER XII

Mechanically Propelled Road Vehicles

To describe many types of mechanically propelled road vehicles used by railway companies is beyond the scope of this work, but those mentioned

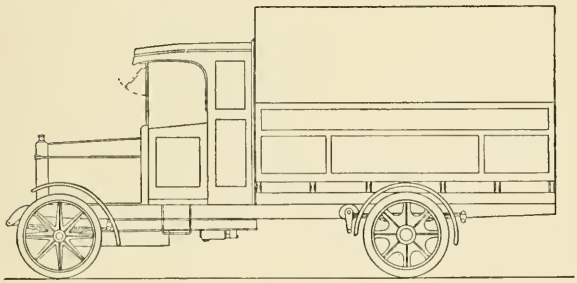


Fig. 135.—Motor Delivery Van

Wheelbase, 12′. Inside length of body, 10′. Inside width of body, 5′ 6″. Inside height of body, 5′ 9″. Overall height of body from ground (approx.) 9′ 5″.

below, and used for the conveyance of goods and parcels traffic, are given as being of interest both to a student and general reader, and are typical of average practice.

At present petrol motor vehicles largely outnumber any other form of mechanically propelled road vehicles for railway parcels and goods cartage work. They are usually purchased by the railway companies from some reliable and well-known maker and from whom spare parts are quickly obtainable in case of emergency.

The underframe or chassis, generally of pressed steel members riveted together, carries the engine in front of the cab, and the drive is either by means of a shaft and gearing, or by chains.

The wheels are made to take heavy solid rubber tyres of standard

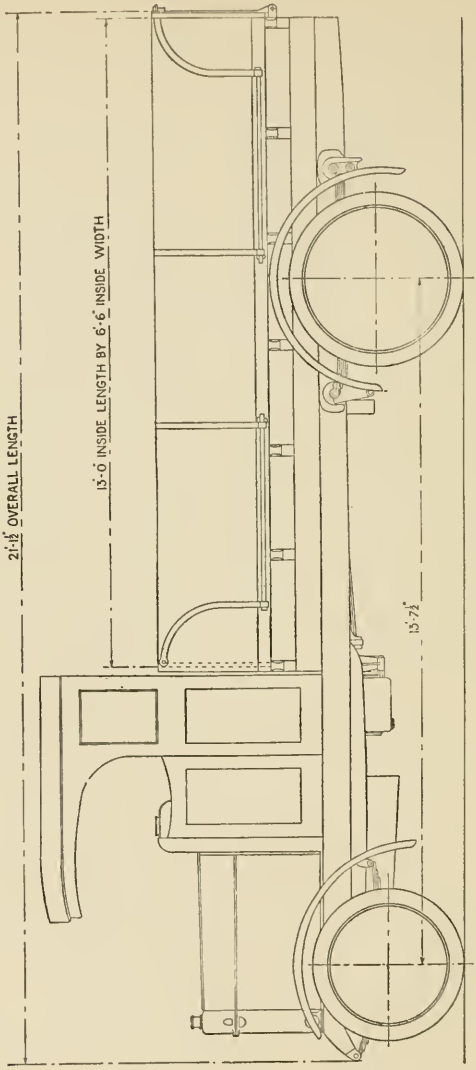


Fig. 136.—Motor Lorry to carry 4 tons

dimensions, and the side bearing springs are likewise made to a standard to facilitate the supply of replacements.

The general practice is to build the frame, cab, and body independently, and, when the latter two are mounted on the former, they are separated by a space of about $\frac{3}{4}$ in., which is sufficient to prevent the cab and body coming into contact with one another when the frame deflects.

Types of Motor Vans.—Fig. 135 shows a very useful van for the delivery and collection of parcels, the load for which is $2\frac{1}{2}$ tons, and the tare 3 tons.

The engine for this vehicle has four cylinders, and develops 25 h.p., and the rear wheels are fitted with a worm drive live axle. The cab is framed in ash and is bolted direct on to the chassis, and the driver's seats, with lockers beneath, are constructed of pitch pine, whilst the body framing is of oak and panelled with mahogany.

Ash hoopsticks, supporting three ply wood, bent to shape and covered with rot-proof canvas bedded in white lead, form a fixed tilt.

The body is supported on oak longitudes and bolsters which are bolted direct to the chassis.

A useful motor lorry for goods cartage is shown in fig. 136, and it is designed to carry a load of 4 tons, and has a tare of 3 tons 18 cwt. The rear end and sides of the body are fitted with hinges so that they may be let down to facilitate loading and unloading of certain goods.

The inside dimensions of the body of this vehicle are: length, 13 ft.; width, 6 ft. 6 in.; and height, 2 ft. $3\frac{1}{2}$ in.; and hinged staples are provided to hold hoopsticks in position when required to carry a loose tarpaulin.

The wheelbase is 13 ft. $7\frac{1}{2}$ in., the engine being from 40 to 50 h.p., and the rear wheels are fitted with a worm drive live axle; both a hand and foot brake are provided.

Sets of Vehicles to speed up Transport of Goods.—At large depots where a great number of cartage vehicles are required a new method has recently been introduced by some railway companies in connection with loading and unloading motor lorries, the plant for working which is briefly described below:

There are three types of vehicles used, viz.: motor lorries, stand trollies, and demountable flats; and the former is standard type of petrol motor lorry chassis, as shown in fig. 137, equipped with a cab and no body, but to the top of the frame or chassis, however, are fixed mild-steel runway plates, and locking gear, also shown in fig. 137, the use for which is described farther on.

The second type of vehicle, i.e. the stand or station trolley, is so named because it does not leave the yard or station at which it works. It is a pair-horse vehicle, and is shown in fig. 138, and will carry a load of $4\frac{1}{2}$ tons, and has a tare of 17 cwt. This vehicle also carries runway plates on its bed and is fitted with scotches.

The usual steel side springs are dispensed with and wood blocks take

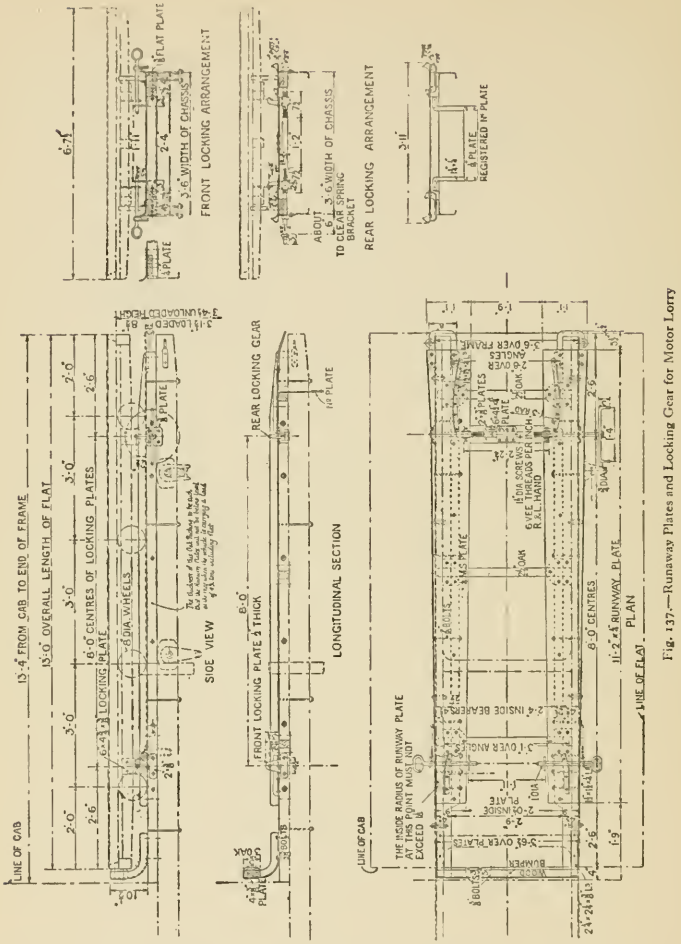


Fig. 137.—Runaway Plates and Locking Gear for Motor Lorry

their place, so that the floor, either loaded or unloaded, remains at a constant height from the ground.

The third type of vehicle, a demountable flat, is simply a tray carried on four axles with eight ball-bearing wheels, and is shown in fig. 139. It will carry a distributed load of 4 tons and has a tare of 10 cwt.

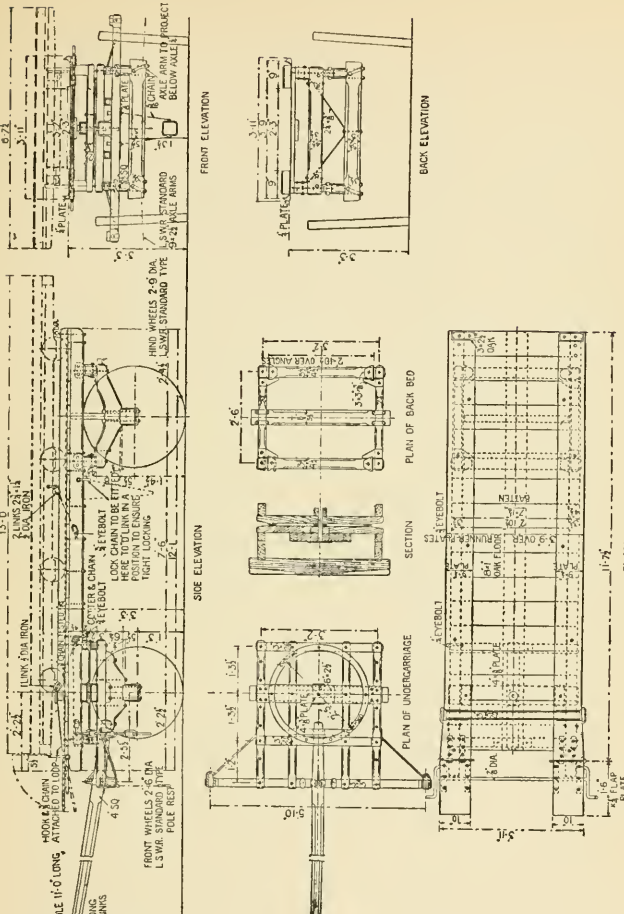


Fig. 138.—Stand Trolley to carry 4½ tons

To work the plant successfully it has been found necessary to provide vehicles to the proportion of four demountable flats and three stand trollies to two motor lorries.

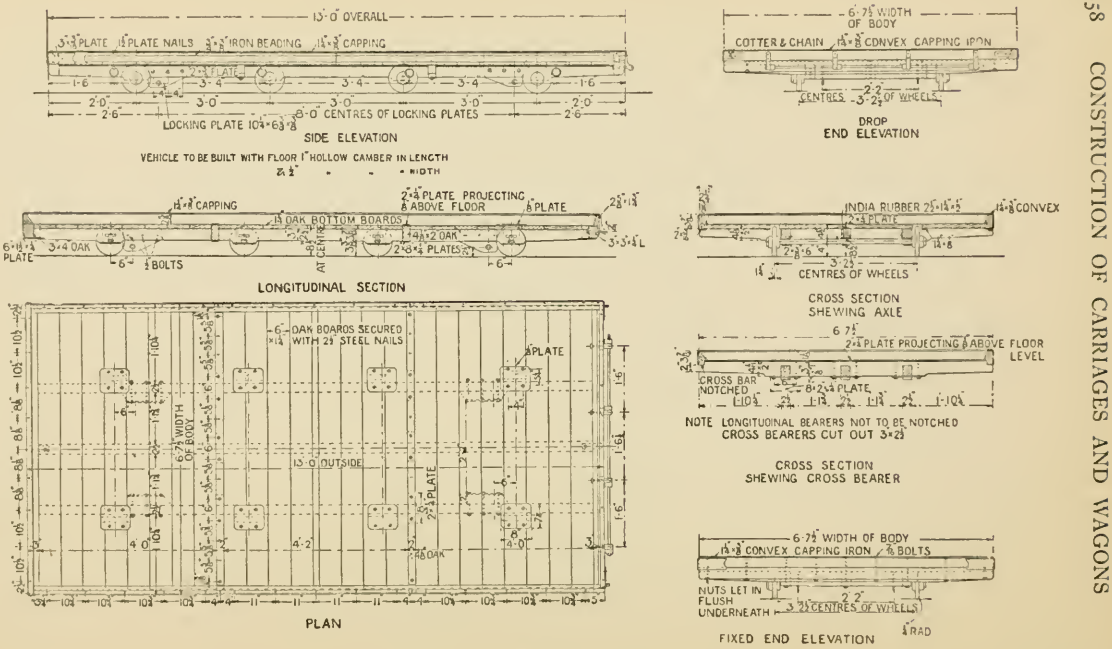


Fig. 139.—Demountable Flat to carry 4 tons

An example of the method of working the plant is as follows:

Each stand trolley carries a demountable flat, the latter being secured to the former by means of chains and scotches. These vehicles are placed against a loading dock by horse power and the flat is loaded with goods, both vehicles are then taken (again by horse power) to some convenient spot where a motor lorry, which has previously transferred its flat to an empty stand trolley, can back into the trolley carrying the loaded flat, and after getting the motor in such a position that the runway plates are lineable with those on the stand trolley, the hinged bridge plates are placed in position, and the coupling chains hooked to motor; it is then possible, under favourable conditions, for one man to transfer the loaded flat from the stand trolley to the motor lorry. Under some circumstances, however, it will be necessary for two men to carry out this operation. It is now only necessary to secure the flat in position, and this is done at the forward end by means of two iron bars passing through holes in steel locking plates, fixed on both the motor and the flat, which coincide when the flat is in position, and at the rear end by means of a shaft provided with two threads (right and left hand) carrying specially shaped nuts which, upon rotation of the shaft, either engage or disengage, as required, with locking plates fitted to the flat. The motor lorry is now ready to proceed on its journey.

Economy is effected by the short space of time that it is required to keep motor lorries standing whilst being loaded or unloaded in this manner as compared with the ordinary method, and with many sets of such vehicles, as described in use, it will readily be seen that the saving of time is very considerable.

Whilst this plant has been adopted by several of the railway companies, others have experimented in different directions, all, however, with the same object in view, i.e. to reduce the amount of time the motor lorries are idle whilst being loaded and unloaded.

Alternative Methods to facilitate Loading.—An effective but more expensive contrivance is that of a turntable arrangement fitted with rails and having a limited radiation, fixed to a stand trolley, on which a flat is carried. This does not necessitate the same degree of accuracy in registering the lineability of the motor and stand trolley, that is required with vehicles fitted with plain fixed runway plates.

Another scheme is that of a windlass and system of wire ropes for transferring loaded flats from stand trollies to motor lorries, whilst some companies have adopted a two-wheeled trailer and special tractor, and all methods have some points in their favour for the particular work which they are required to carry out.

The tendency is ever towards making the mechanical element carry out a maximum amount of work in a given time.

Electrically propelled Platform Trolley Sets.—In connection with the conveyance of parcels, on station platforms and at wharves where battery charging facilities are available, the electric platform trolley has been found very useful.

These vehicles generally have four wheels and are from 7 to 9 ft. long by about 4 ft. 6 in. wide, the height from ground being about 1 ft. 9 in.

The driver is accommodated in the front of the trolley, and generally controls the vehicle by means of a lever and steering wheel, and the power is obtained from electric batteries which are carried beneath the floor of the vehicle, where they are easily accessible for recharging purposes.

These trollies are fitted with couplings at the rear, to which may be attached several trailers, the number depending upon the weight of load and condition of the road upon which they are to travel.

RAILWAY-CARRIAGE LIGHTING

BY

SIR HENRY FOWLER, K.B.E.

M.Inst.C.E., M.I.Mech.E.

Railway-carriage Lighting

CHAPTER I

Carriage-lighting Requirements and Economics

Ever since railway coaches were first covered in, some attempt has been made to provide artificial light for the interior of the compartments so that travellers may be able to see whilst travelling by night. How crude many of these attempts have been is in the recollection of all persons of middle age; and the majority of travellers have had experience, at one time or another, of the poor and uncertain light given by the oil lamps once so largely used in this country. These were not, however, the first attempt at lighting, for candles in lanterns were one of the earliest forms; and even in 1900, at the Paris Exhibition, passenger coaches for a Continental country were shown in which this form of illumination was adopted, there being one candle for each two compartments. It need scarcely be said that such lights do not give sufficient illumination for reading by; but they probably meet the chief needs of the passengers, and enable them to move about and pass in and out without coming in collision with one another. Those were the only points required in early types of coaches in this and other countries; but, although the necessity for a better light was soon felt, difficulty was realized in giving this. It obviously would not do to carry a fairly light oil, such as petroleum, in any quantities, and difficulty was experienced in obtaining a satisfactory windproof lamp for this class of lighting.

Rape-oil Lamps.—Recourse had to be made to rape oil burnt in a broad burner in a lamp fixed high up in the roof of the coach. An illustration of this class of lamp and burner is given in fig. 1, and it will be seen that the container for the oil is placed in the body of the lamp, and the burner is underneath this, and lies in about the centre of the glass globe, which projects through the roof into the compartment. The oil passes from the container in the manner shown down to the burner. On the photometer bar these lamps will give a little over 2 candles in a horizontal plane with a consumption of 360 gr. of rape oil per hour, which, with a container holding 0·075 gall., allows a light to be given for 13 hours with one filling. It was the wick, however, and not the oil supply, which governed the length of

time light could be obtained without trimming, and this made the useful period for the lamp about 6 hours. There were very many disadvantages in the use of these lights, one being that the oil tended to leak out of the burner into the bottom of the glass, and not only obscured some of the light, but made the appearance of the bottom of the globe anything but attractive. On the score of expense and inconvenience alone, these lamps were not a success, as it may be taken that the cost per burner was about twice that of oil gas, whilst considerable inconvenience was experienced in removing the lamps for filling and trimming, and replacing them in the coaches. The light given was, from modern standpoints, very deficient; and in no case sufficient to allow reading to take place in comfort. This class of lighting has been spoken of in the past tense, not because the writer is unaware that it is still used in some cases, but because it hardly fulfils the requirements of modern railway working, and it will doubtless before long disappear entirely.

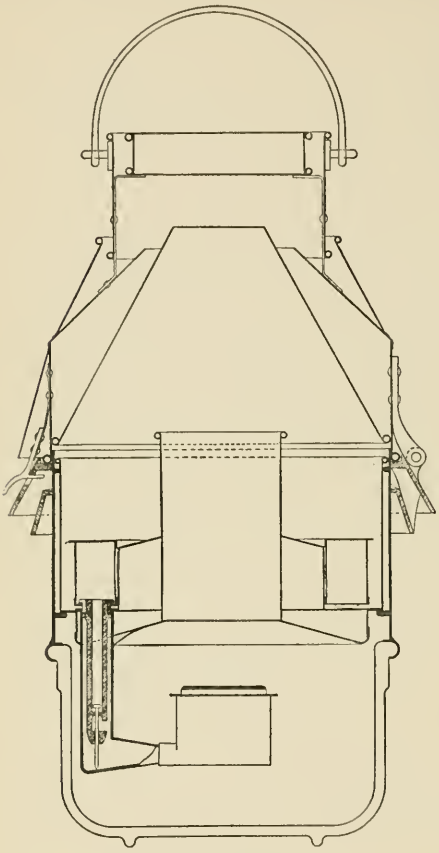


Fig. 1.—Rape-oil Railway-carriage Lamp

Question of Cost.—The present systems of illumination divide themselves into lighting by means of oil gas and electricity, and there is very considerable divergence of opinion as to which system is the cheapest and the most advantageous to employ. This question is not as simple as it might at first sight appear, even from the standpoint of economy. A railway company, before making an exchange, has to look not only to the cost of an

article manufactured, such as oil gas, but also to the question of what capital will be wiped out if an alteration is made; and, therefore, if a price is to be fixed for the cost of oil gas per 1000 c. ft. for comparison with the proposed replacement of this type of lighting with electric lamps, the interest, &c., on this capital has to be neglected. If the number of coaches to be lighted is to be increased, the same cost must be taken if the existing works will supply the gas required, or perhaps even a still lower charge may be made, for there are always certain standing charges, such as supervision, &c., which do not increase, at all events proportionately, with the amount of gas made. With regard to electric light, it is always a somewhat difficult matter to ascertain practically what amount of coal should be charged for the energy necessary to drive the dynamos which generate the current, as any tests between two trains are not likely to be carried out with exactly the same climatic conditions, at the same temperature, &c., and these are points which materially affect the results, although this item is small and can probably be approximately arrived at theoretically. The wages on maintenance may be excessive if a fitter is required to attend, for any reason, a few coaches only. It is probable that there are cases in which each is the most suitable, and it is therefore proposed to put the facts of each case before the reader.

Gas versus Electric Light.—There are, however, a few points for and against each method which it will be well to state briefly. For gas it may be claimed that, when once the coach is fitted and the reservoirs under the carriage body filled, it is always available for use, and, however long the coach has been standing, any porter can light the lamps whenever they may be wanted. It has been stated that the presence of a cylinder of gas at high pressure may form a danger in collision by an escape catching fire from any cause, but recently a special type of apparatus has been devised to obviate this by automatically shutting off the gas in case of a sudden rush caused by the breakage of a pipe. This special apparatus is fixed on the outlet of the storage cylinders. With electric light the coaches are usually independent, and may be worked to any part of the line without the necessity of having to return periodically to some particular station to be filled in order that burning may continue. They must, however, always receive some attention from time to time from skilled mechanics. The electric lights can be much more easily lighted and extinguished, and this is a point to be considered especially with sleeping cars; they can also be readily placed in any position, and need not be fixed in the roof of the compartment.

There is one point which, in any discussion, must not be lost sight of; and that is that modern requirements call for some arrangements for cooking on all, or nearly all, important trains, and gas is found to be a great convenience in this respect, the same supply serving both for this purpose and for lighting.

Disposition of the Lamps.—A matter which is discussed from time to time, and yet never completely settled, is the best position in which to fix the lights in the compartments. With the old oil lamps, the only positions used were the centre of the roof, or the middle of the division when one light was made to serve two compartments. With gas, and with the use of

clerestory roofs on some lines and the call for better lighting, the question was raised again. In many cases the first method of dealing with the matter was to use a deep lamp (fig. 2) with one or two burners, in the centre of the compartment, and this plan is still adopted by some companies. A lamp is sometimes fixed on either side of the clerestory; whilst, with corridor stock, at least one line uses two lamps in the lower portion of the roof and directly over the seat. The disadvantage of a centre light is that to get it to fall on the paper or book it is necessary to turn somewhat to the lamp; whilst the second method mentioned means a duplication of the lights and somewhat extra expense. The advent of electric light opened up fresh possibilities for the arrangement of the lights, and one which was early tried was placing the lights in the ideal position from a reader's standpoint, viz. on the division of the coaches at the back of the seats. Unfortunately, although this is an excellent position for throwing light on to one's paper or book, it is very uncomfortable for the passenger opposite, who, every time he raises his head, has a light shining fully in his face. The result has been that although some companies still adopt this plan, it has not become by any means the universal method of arrangement. Probably the best method is to place one lamp over each corner of the compartment close against the roof and over the seats. It may be mentioned that on certain carriages of the Prussian State Railway, electric lamps with shades shaped as in fig. 3 were used, and

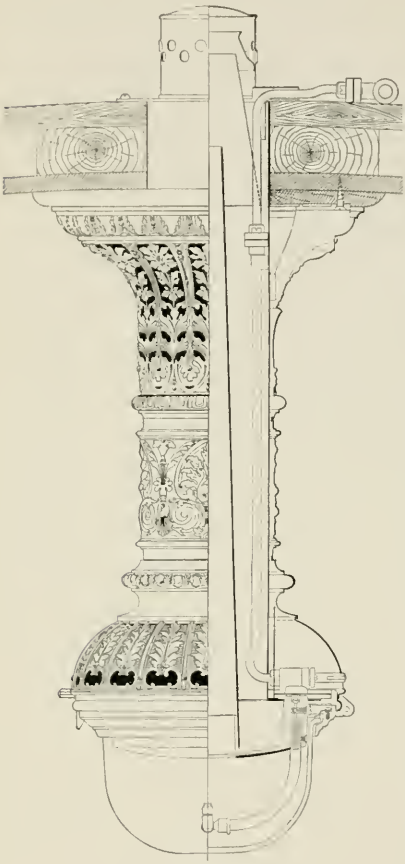


Fig. 2.—Clerestory Roof Lamp

these seem to meet the difficulty mentioned with regard to lights placed over the back of the seats. The lamps used were long incandescent electrical ones. The shade, whilst throwing the light on to the papers of the passengers on the seats beneath, effectually prevents any rays falling on the eyes of the passengers opposite. The only disadvantage is that the top portion of the compartments is in darkness.

Fig. 3.—Electric Lamp and Shade on Prussian State Railway

Importance of Reflecting Surfaces.—The amount of light required has steadily grown from the 2 candles of the oil lamp to the comparatively large candle-power provided to-day, reaching, in many cases, as high as 50 or more candles per compartment. This large increase is undoubtedly partly due to the competition between gas and electric light, as each development in either has resulted in an effort being made to assert the superiority of either by giving an increased illumination. The actual illumination is, to a certain extent,

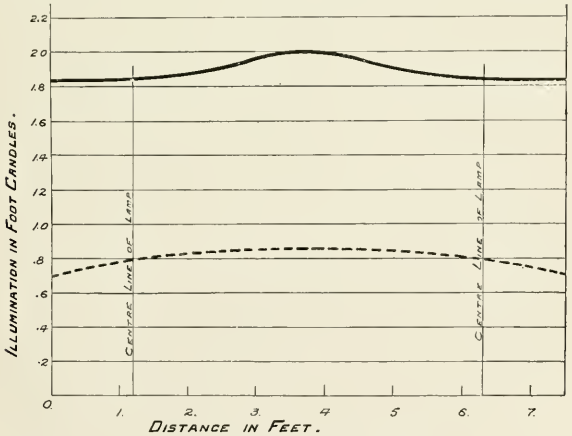


Fig. 4.—Illumination Curve in a Compartment

dependent upon the reflector employed, and this should be designed to give the light downwards or on the roof, and not on either the windows or sides of the compartment, as the latter usually are cut up with luggage racks, &c.

A point that does not always receive the attention it should is the colour of the roof, as, if good reflecting surfaces are provided, it is possible to increase materially the actual illumination of the points required, and to do so in the most agreeable manner, the light being well and evenly diffused. It is not only the roof that needs attention, but all the fittings should be as light as possible, bearing in mind the necessity for keeping them clean. This should apply even to the cloth used for the backs of the seats; and this seems to have been in the mind of those in charge of the construction of the coaches on some Continental lines, on which a light-greyish cloth is employed in many compartments. This is of excellent reflecting quality, and gives the carriages a very light appearance, but tarnishes more easily in use.

The actual illumination of a line 1·5 ft. above the edge of a seat in terms of foot candles is given in fig. 4, the gas lights being arranged as shown on the diagram. If the actual candle-power of the lamps only is considered, the illumination would have been that shown by a dotted line, the difference being due to reflection. It may be stated that the lighting of this compartment was everything that could be desired.

CHAPTER II

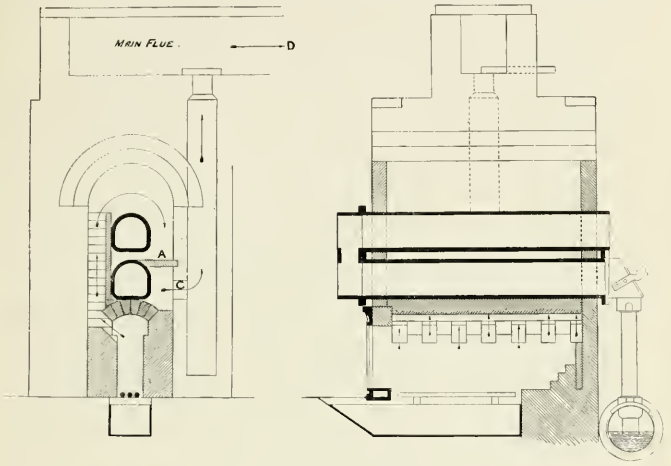
Gas Lighting

Oil gas as used for carriage lighting is manufactured in retorts, and after passing through condensers, &c., in order that all tar, moisture, &c., may be removed, is compressed in pumps and stored in large cylinders connected with the supply pipes in the stations or carriage sidings.

Class of Oil.—The oil used for gas-making is usually a solar distillate which in fractional distillation comes off between the burning and the lubricating oils. At one time Scottish shale oil was almost exclusively employed, but now products from American or other petroleum are used as well. The oil has a specific gravity of 0·840 to 0·860, and a flash-point (close test) of about 200° F. It should not contain more than ·5 per cent of sulphur. In colour it varies from iridescent yellow to a reddish tinge. Usually the specific gravity and flash-point are the only points tested before using an oil; but some railway companies test a small quantity in a vertical retort of small diameter, and by this means arrive at an estimate of the value of the oil as regards both illumination and make. If such a plan is adopted it is well to use a pyrometer, and have the temperature of the furnace well under control so that the actual conditions during testing may be kept constant.

Arrangement of Retorts.—The oil is gasified in cast-iron retorts,

usually of D section with the flat portion at the bottom, and placed in pairs one above the other. The oil is fed into one end of the upper retort, and passing along this, enters, as oil vapour, the opposite end of the lower retort by means of a connecting mouthpiece. In this lower retort the vapour which has been formed is " fixed " and converted to permanent gas, finally



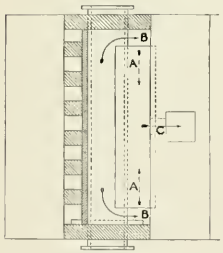


Fig. 5.—Single Set of 10-in. Retorts

passing off into the hydraulic main directly beneath the point where it entered the higher retort. The method of heating the retorts varies somewhat in detail, but the following description is probably typical of British practice. In small works, the retorts are set with a single pair over the furnace, as seen in fig. 5. In this case the flame and hot gases are carried up a series of openings by the side of the wall of the bed, and pass into a fairly large space over the top of the higher retort. Resting on the top of the bottom retort is a length of tiles A, A, which is built into the wall opposite the one up which the gases enter. These tiles are not carried to the end walls of the bench, but openings B, B are provided at this point through which the gases descend, and these, after passing along the side of the bottom retort and under the tiles, finally make an exit through the opening C into the main flue D. It is, of course, necessary to provide a chimney giving a sufficient draught to

burn the coke usually employed for fuel. In most works where any quantity of gas is made two pairs of retorts are set in one arch, and this leads to economy in fuel, &c. In this case the arrangement shown in fig. 6 may be used. This, it will be seen, follows closely the arrangement of the single setting. The hot gases from the furnace now pass from the top of the arch and enter a kind of chequer-work, and, passing over the top of the

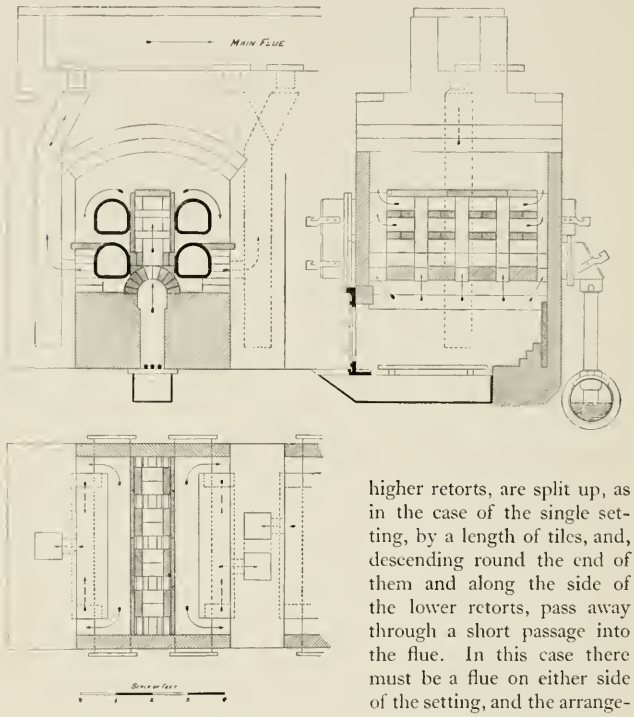


Fig. 6.—Double Set of 10-in. Retorts

higher retorts, are split up, as in the case of the single setting, by a length of tiles, and, descending round the end of them and along the side of the lower retorts, pass away through a short passage into the flue. In this case there must be a flue on either side of the setting, and the arrangement of these, where a number of settings are built in one bench, is shown on the right hand of the plan in fig. 6. The small furnace arches are often made of refractory sandbricks, as these allow of perfect joints being made, as well as being capable of strongly resisting the heat of the fire. The rest of the settings should be of best firebrick.

Manufacturing the Gas.—The oil is stored in underground tanks, shown at A in fig. 7, which gives a general plan of a works, and they are conveniently situated for being filled from travelling rail tanks. By means

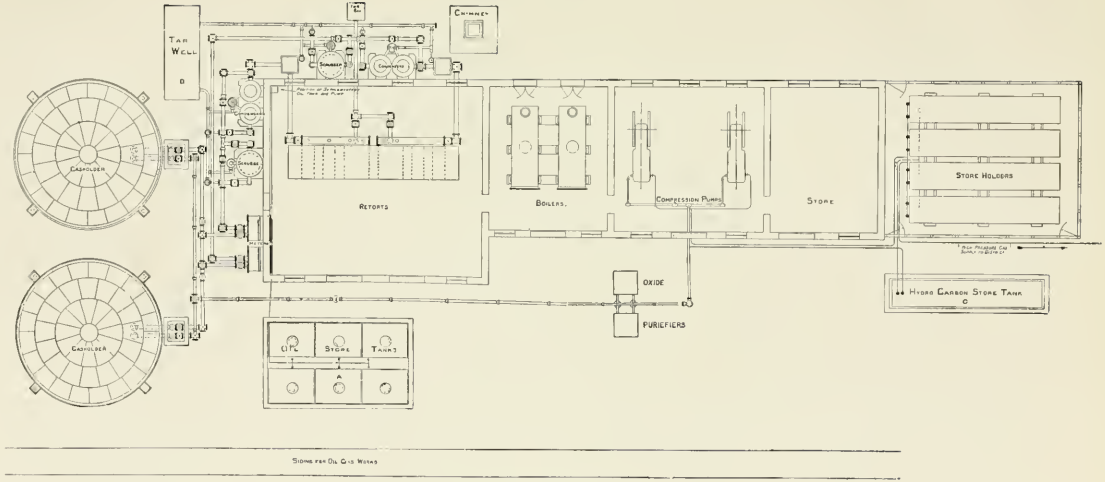
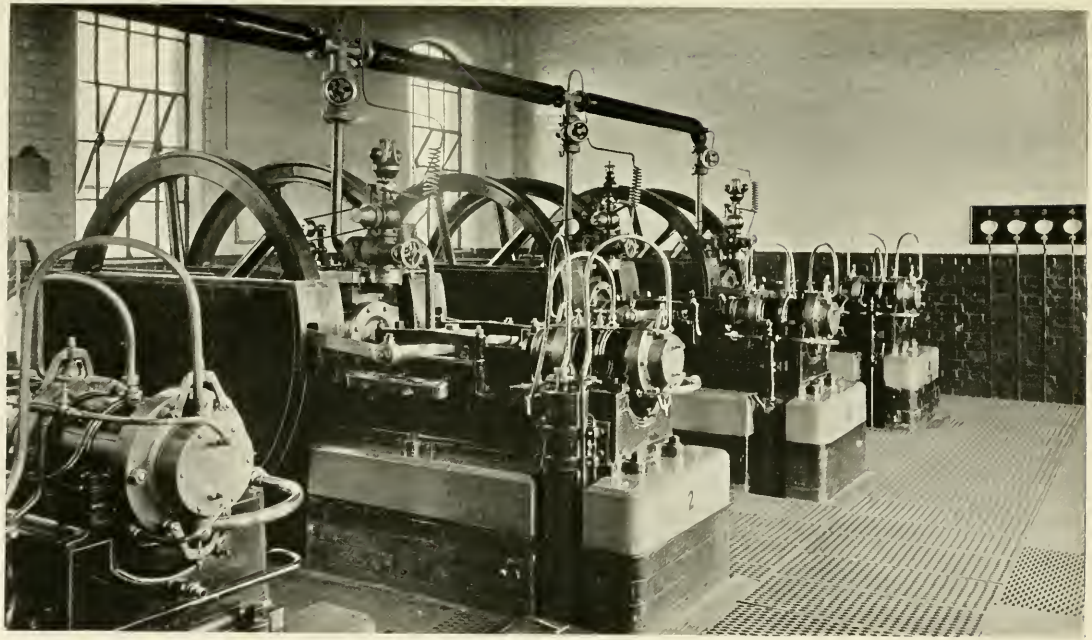


Fig. 7.—Plan of Oil-gas Works

of a pump, a small supplementary tank on the retort-house wall is filled with oil, and from this a pipe is connected to a meter supplying an auxiliary tank in which a constant level is maintained by a ball valve. From this tank a pipe runs along the back of the retort bench, with connections leading to each top retort. At the end of these connections is a " micrometer " cock, from which the oil is fed into a funnel fixed on a U pipe attached to the cover of the top retort. The object of this U pipe is to create an oil seal and so prevent any escape of gas as the oil is fed into the retort, whilst it forms a relief valve should the retort pressure become too great. The oil is run into each top retort at the rate of about 3 gall. per hour, which makes about 220 to 230 c. ft. of gas. The actual quantity depends upon the heat of the retorts, as the oil supplied and gas made may be halved or doubled under certain circumstances. The proper amount is ascertained by noting the colour of the crude gas issuing from a trial cock in the lower retort. This colour should be a lightish yellow-green, and the oil supply is varied to obtain this; if too much oil is being supplied it will be white, and if too little, a darker colour. Where the oil is metered the gas made per gallon of oil can be directly determined from the meter readings. From 78 to 80 c. ft. is the usual average. In the top retort is a light iron tray on to which the oil drops, as this prevents the retort itself being cooled and damaged by the entering oil. The bottom retort frequently gets a deposit of carbon, not unlike coal-gas carbon, on it; but if the lids are left loose for an hour each day this will burn off and not accumulate. Much " carbon " is generally an indication of overheating of the retort. From the bottom retort the gas passes downward through a " seal " of 1 in. of tar into the hydraulic main, situated at the foot of the retort bed just below floor level. Here the first heavy portion of the tar in the gas will be deposited, and runs through a small tar box or tank into the tar well shown at B in fig. 7. If no steps are taken to cool this main it is liable to become " pitched up " with thick tough tar, and in some cases water is run in to prevent this. A much better practice is, however, to pump cold tar out of the tar tank and pass it through in a fairly copious stream. From the hydraulic main the gas goes first of all through annular condensers, usually about 13 ft. high and 2 ft. 8 in. outer and 1 ft. 10 in. inner diameter. Here most of the remaining condensable liquid is deposited, and passes through seal pots to the tar tanks. If the gasifying has been carried out properly, the tar from these seal pots will contain no oil. This can be readily judged by dropping a spot of the liquid on a sheet of blotting paper, when, if oil is present, it will show a lighter colour outside the black mark of the tar proper. The next vessel through which the gas passes is the so-called scrubber, where it does not meet the stream of water usual in coal-gas scrubbers, but passes through fine wood chequer-work in a tank the same size externally as the condensers. As an alternative to the wood chequer work, layers of coke 2 ft. thick have been successfully used. In one instance tests showed that the tar-fog was reduced from 100 to less than 3 gr. per 100 c. ft. of gas. After going through the meter the gas finally passes into a gasholder for



ENGINE AND COMPRESSOR ROOM IN OIL-GAS WORKS

[Facing p. 272, Vol. I

storage before use, although in some few works it is put through lime purifiers and water scrubbers. Analysis has shown that oil gas may contain as much as 80 to 90 gr. of sulphur per 100 c. ft. of gas, or about one-third of the total sulphur in the oil. As all this sulphur is in the form of sulphuretted hydrogen it is cheaply removed by passing the gas through oxide of iron purifiers. If these are connected to the suction main between the gas holders and the compressors no additional back pressure is caused in the retorts. In exposed situations the gasholders will act as condensers during the winter months and a thin tar will be deposited upon the surface of the water. This should be siphoned off annually, otherwise it may be re-evaporated in hot weather and cause blockages in the small high-pressure distribution pipes. In recent years it has been found an advantage to add to the oil gas up to 20 per cent of coal gas, and where this is done the latter is admitted to the inlet main to the gasholders. Generally, the whole of the works are in duplicate, so that, in case of repairs being required to any portion, the manufacture of the gas is not interfered with.

Compressing the Gas.—The pressure of the gas during manufacture should be kept as low as possible, and may vary from 3 in. of water in the retorts to 1 in. in the gasholder The gas having been manufactured by the method already described, it is compressed in specially designed steam-driven pumps to a pressure of 150 lb. above atmosphere. These pumps are usually direct-acting, the steam cylinder, with a boiler pressure of 60 to 80 lb. per square inch, being 10 in. diameter and the gas cylinder $6\frac{3}{4}$ in., the stroke being $12\frac{1}{2}$ in. In order to get over the dead points of the stroke, a connecting-rod, crank, and fairly heavy flywheels are provided. The general arrangement of an engine house will be gathered from Plate X. Naturally the compression leads to considerable heating in the gas cylinder, and in order to keep this as low as possible the cylinder and the pipe leading directly from it are water-jacketed, the stream of water passing through being used in the boilers which provide steam for the engines. In order to prevent the gas being compressed to too high a pressure the outlets of the gas cylinders are connected to the inlet gas pipe, there being a non-return valve in between, which opens when the gas exceeds a certain pressure, and allows it to pass back into the low-pressure main. The gas passes from the compressor into large steel storeholders. These are cylindrical vessels, usually about 4 ft. 6 in. diameter by 25 ft. long, and built up of steel plates about $\frac{1}{2}$ in. thick. The number of them employed varies with the size of the works and the demand for storage. If the plant is only worked intermittently the provision of adequate storage is a great advantage. Often in small works the compressor will be driven by a gas engine, which can be started up readily, and allows of any gas made and lying in the gasholder being compressed into the high-pressure store-holders. In such case, arrangements can be made to connect one or more of the storeholders with the compressor, so that, when the pressure falls in them generally, the gas may be pumped from one section so as to maintain the requisite pressure in the remainder.

Fuel Consumption; By-products.—Before quitting the question of manufacture there are one or two points yet to be dealt with, and one of them is the question of fuel consumption. Coke is generally used in the furnaces of the retort benches, and the amount burnt will depend greatly on whether single or double retorts are used. It may be taken that 168 lb. per 1000 c. ft. of gas made is a fair consumption in the former case, and 112 lb. in the latter with intermittent working.

The manufacture of oil gas gives rise to two by-products, viz. tar and a light oil or spirit. The former, as has been stated, is deposited in the hydraulic main and condensers, and passes into the tar tank shown in fig. 7. This tar is about the same specific gravity as water, and is difficult to separate from this substance if it should chance to become mixed with it. It can be burnt in specially constructed burners in the flues of cylindrical boilers, or can be sold for various purposes, the price obtainable being, however, subject to considerable variation. It has also been successfully used as a fuel for the heating of brass melting crucibles, being used in conjunction with compressed air. The light oil or spirit is generally known as "hydrocarbon", and consists of the more readily condensable hydrocarbons which come down in liquid form during compression and subsequent cooling. It consists of a large number of complex hydrocarbons and has a specific gravity of about 0·79. It is found in the storeholders; and pipes are inserted in the bottoms of these to lead it to a special storage tank, shown at C in fig. 7. It is highly inflammable and very volatile, and is sometimes used for the enrichment of coal gas, and possesses a characteristic odour. As a rule, 0·77 gall. of this substance and 4·7 gall. of tar are produced from 1000 c. ft. of gas, which has required 13·3 gall. of oil in its manufacture. If the make of gas per gallon of oil is increased from 75 to 78 c. ft., the amount of tar is reduced to 3·7 gall., and 1000 c. ft. will require 12·8 gall. of oil Where coal gas is compressed with the oil gas it is enriched by about 10 per cent, so that the total calorific value per cubic foot of the mixture is greater than the sum of the same proportions of the gases compressed separately. This reduces the quantity of hydrocarbon residue to about ·71 gall. of ·82 specific gravity. This hydrocarbon has also been distilled by steam, and yields 75 per cent of spirit suitable for use in air-gas plants and for motor vehicles. Unless chemically purified, however, there is a tendency for a gummy deposit to accumulate on the valve stems, and this necessitates frequent cleaning.

The oil gas has a calorific value of 1200 B.Th.U. per cubic foot after compression and an illuminating value of 10 candles per foot when first made, but this is reduced to about 8 candles after it has been compressed, owing to the lighter hydrocarbons having been liquefied. These candle powers are obtained, as is always the case with high-power illuminating gas, in small burners consuming about 1 c. ft. per hour.

Filling the Coach Cylinders.—From the storeholders the gas is conveyed in strong steel pipes, usually $\frac{7}{8}$ in. internal and $1\frac{5}{16}$ in. external diameter, to the station and sidings at which the coaches are to be charged.

As may be readily understood, it is necessary to prevent any possibility of escape, and this is guarded against at the joint by making the couplings and pipe ends with right- and left-handed threads. One pipe has its end left chisel-shaped and the other flat, and by means of powerful pipe tongs these are made to ensure an absolutely tight metal-to-metal joint. The piping is liable to corrosion from the ashes it is laid in, if this is not specially guarded against. This is done by placing it in creosoted troughs and filling these in with pitch, and thus making an impervious covering for it. Care must be taken that the pipe does not rest on the bottom of the troughing or in contact with any substance liable to corrosion; otherwise there is a chance of the troughing rotting away and allowing of corrosion setting up in the pipe, with subsequent trouble.

At intervals along the roads on which the coaches are to be filled T's are placed on the filling main, and to these specially designed valves, usually fixed rigidly in circular cast-iron boxes, are fitted. On these valves are attached, when necessary, lengths of very stout rubber pipe with canvas insertion, which can be coupled up to a connection on the coach it is necessary to fill. Every care must be taken to free the gas from any liquid hydrocarbon before it enters these rubber pipes, or they will tend to be rotted by it. In some cases storeholders are fixed close to the points at which filling is to take place, in order to prevent the pressure falling owing to the length of pipe the gas has to travel through. A plan of the arrangement for filling valves, with their " pots ", is shown in fig. 8.

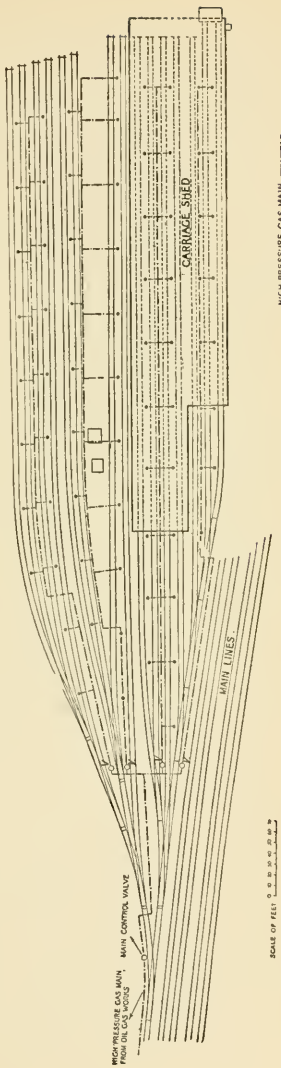


Fig. 8.—Plan of Sidings and Carriage Shed showing Filling Pots

In cases where it is necessary to fill a few coaches which do not travel to a filling station, travelling storeholders are often resorted to. These consist of cylinders in which the gas is stored, placed on a truck or wagon. The storage sometimes consists of two cylinders 18 ft. 6 in. long by 4 ft. 2 in. in diameter placed side by side, whilst in other cases it may be a single

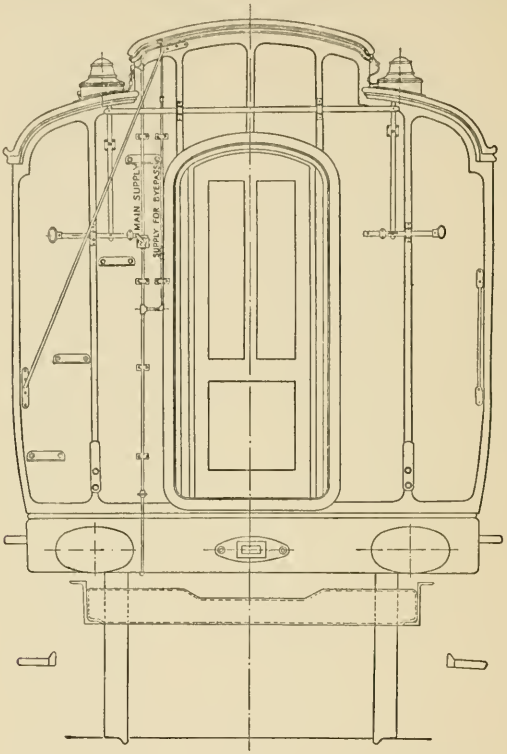


Fig. 9.—End View of Coach, showing Arrangement of Gas Pipes and Control Levers

vessel 20 ft. long by 6 ft. 6 in., or, as is extensively used by one English company, about thirty small cylinders placed crossways on the wagon and arranged in five sections. In each case the amount of gas carried is from 4000 to 6500 c. ft. before compression to 11 atmospheres. With the first and last methods, arrangements can be made for filling the coaches from one cylinder or section as far as possible, and then completing the filling from another in which the gas stands at a higher pressure.

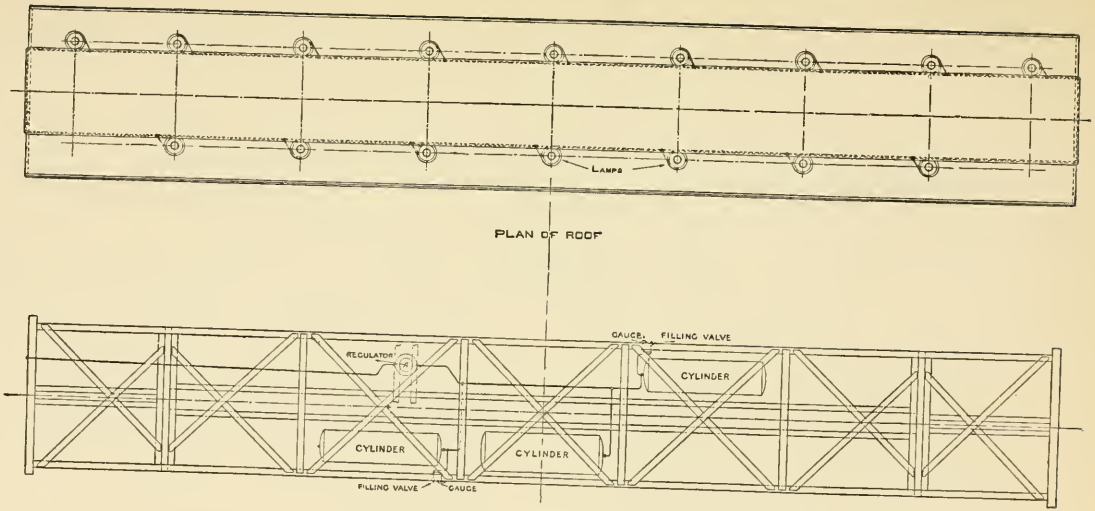


Fig. 10.—Arrangement of Gas Fittings on Railway Carriage

Coach Cylinders and Connections.—Under the framework of the coaches are fitted the cylinders in which the gas is stored for the journey. These may be from 18 to 24 in. in diameter, and from 3 to 9 ft. in length —the dimensions of the coach and the lighting required determining the measurements and also the number fixed, which varies from one to four. A general arrangement of the fitting up of a coach is shown in fig. 10. The cylinders are usually charged with gas at an initial pressure of 105 lb. above the atmosphere, but this is of course far too high for actual use at the burners, where it should not exceed a few inches of water. To allow of this a regulator (see A in fig. 10) is provided. A detail drawing of this is shown in fig. 11, and it will be seen that the gas is allowed to pass through a needle valve A to the under side of a leather diaphragm B. The latter is connected by levers C C with the needle valve, and as the pressure is exerted under it

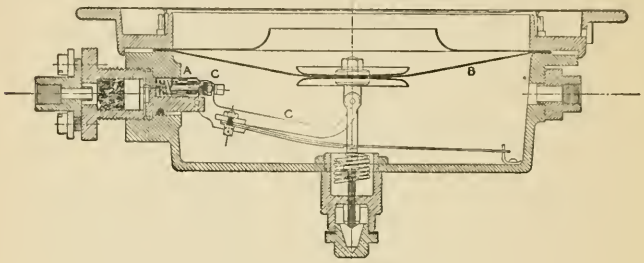


Fig. 11.—Gas Regulator for Railway Carriage

the needle valve is closed. These regulators prevent any fluctuation of light, whether a single burner or twenty are employed. The pipes for supplying the lamps are usually of $\frac{3}{8}$-in. internal diameter, and pass from the regulator up the end of the coach to the lamps on the roof.

The Flat-flame Vertical Burner.—In spite of various improvements which have been made in the methods of burning oil gas, some is still consumed in flat-flame vertical burners. A type of a lamp for this purpose is shown by fig. 12. It will be seen that the lamp itself consists of a cast-iron cylinder dropped through the roof of the coach and fastened at the bottom by an annular ring. The bottom of the casting projects inwards, and on this the reflector A rests. This is a thin iron casting, the lower side or reflector proper being enamelled white, whilst the centre portion forms a chimney for the escape of the burnt gases. These pass through the cone B and cover C, which is so arranged as to prevent the light flickering when subjected to the complicated air currents met with when running, and particularly when passing through some tunnels. The incoming air is supplied through vent holes D, and follows the path shown by arrows on the illustration. The gas supply is taken through the brass pipe E, which is hinged at F and G so that it may be withdrawn from the lamp without

actual uncoupling. The burner lies in the glass globe H, which is fastened from beneath by the brass ring J, which is attached by screws to the annular iron ring K. This permits of a broken globe being easily replaced. The ornamental ring L of thin burnished brass gives a finished appearance to the lamp from the inside of the coach. The enclosed nature of these lamps has naturally led to attempts being made to make use of the waste

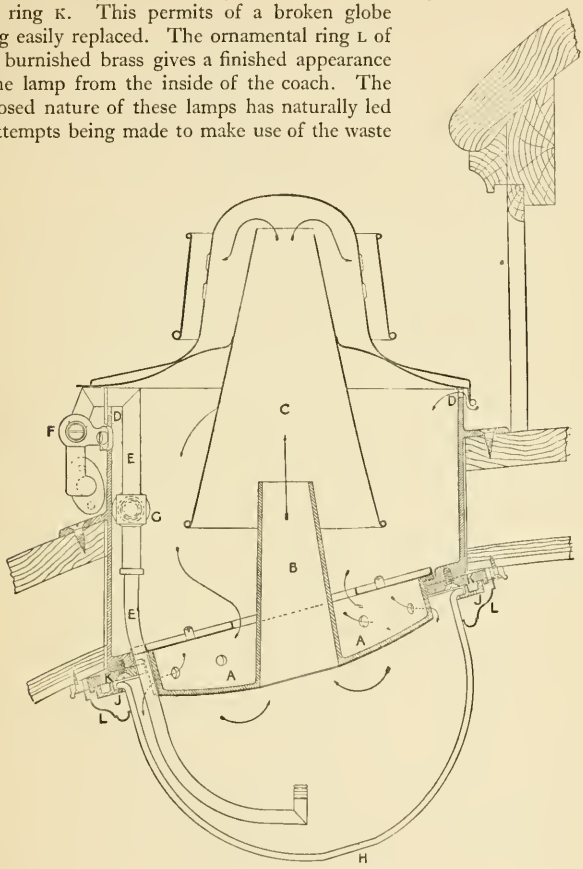


Fig. 12.—Flat-flame Railway-carriage Lamp

gases to heat up the air necessary for combustion and so increase the efficiency of the lamps. Many of these have been successful; but the great difficulty in obtaining the best results is the small depth allowed to the lamp by the loading gauge, which prevents the incoming air being long in contact with any plate the other side of which has been heated by the

waste gases. Of lamps of this type which have given successful results are the "Thomas and Still" and the "Coligny Welch". The former of these has two or three horizontal burners, to which air is supplied after passing partially round an annular space directly over the reflector proper. The latter burns the gas in a mushroom flame, the products of combustion passing up small copper tubes round which the air for combustion passes.

Incandescent Gas Lamps.—The greatest advance in the economy of burning oil gas, as with coal gas for station lighting, &c., has, however, been in the adoption of the incandescent mantle. Oil gas has a calorific value of about two and a half times that of coal gas, and a low percentage of incombustibles, and the incandescence of the rare earths of the mantles is largely increased by the consequent high flame temperature. As long ago as 1902 this type of lighting was being successfully applied on the Eastern Railway of France, where small upright mantles were used. These have, however, now been superseded by small inverted mantles, which not only seem to resist the effects of shock better, but have a higher efficiency and cast no shadows. The light given by one of these burners, consuming about 0·65 c. ft. of gas per hour at a pressure of 8 in. of water, is about 25 candles. A larger burner is also employed which, with a consumption of 1·05 c. ft. per hour, gives a light of 50 candles. It will be noted that not only is the candle-power high, but the gas consumed is low. This is an important point, as it lengthens the time that the burners may be used without recharging the storage cylinders. With ordinary burners the latter are usually arranged to supply the lights for 16 hours, but the use of incandescent burners raises this to about 40 hours. This is due to the fact that the high illumination given by the mantle permits of fewer lights being used; as it will readily be seen that the candle-power with one mantle is far greater than that obtained from two or even three burners each giving 8 candles for a consumption of 1 c. ft. of gas per hour. One of the difficulties with this light is the trouble experienced in lighting it. As a rule, the gas lamps of a coach are lighted by means of a torch of some description held over the chimney of the reflector. This, however, will hardly do with an incandescent burner, as the slight explosion which ensues tends to break the mantle. This is overcome by using a small bypass light, which projects from the reflector in such a manner as to ignite the main burner and render the mantle incandescent. The mantles have a life of about six weeks when in regular use, and this may be looked upon as satisfactory when one considers the shocks to which they are subjected.

Extensive experiments in the use of acetylene as an enricher for oil gas[1] were made some years ago on the Continent, and somewhat similar experiments were carried out in this country by the writer in 1897.[2] This system, offering as it did an equal or better light for a greater number of hours without recharging of the storage cylinders on the coaches, was extensively used on some railways; but the improvements which have

[1] *Journal of Gas Lighting*, Vol. LXIX, p. 1248.
[2] *Proc. Inst. C. E.*, Vol. CXXXIV, 1897–8, Part IV.

rendered it possible to use an incandescent mantle in a railway coach are so economical, that the acetylene oil-gas mixture has been, or is being, abandoned wherever adopted.

CHAPTER III

Electric Lighting

Many attempts were made, soon after the general introduction of electricity for lighting purposes, to adapt it for train lighting. The problem at first sight appeared to be a fairly simple one, but the varying speed of the carriage axles, which seemed at first to offer so admirable a means of obtaining power, proved a stumbling-block. Recourse was then made to separate plants fixed on the locomotive and elsewhere, but for various reasons these did not prove successful.

The first type of lighting which proved a permanent success, and which was adopted on anything like a large scale, was the Stone's system, to be described later. In recent years great attention has been given to the electrical design of the machines of the various systems, with a view of obtaining greater efficiency without in any way affecting the reliability. The development of satisfactory metallic filament and gas-filled lamps has made it possible, on the one hand, to obtain from a comparatively small machine the necessary current for the lighting of the largest modern carriage, and on the other, where desirable, to light more than one coach from a single equipment with a corresponding decrease in cost.

Considerable progress has been made in the adoption of through control of the electric lighting of passenger trains, which enables a guard, for example, to switch on or off half or full lights on a day train as it passes through tunnels. This result is obtained by means of magnetic switches, usually fixed in the ends of the carriages, and operated by control wires running the full length of the train and terminating in master switches in the guards' vans at either end.

Stone's System.—This method depends on the carriage axle for its power, but an ingenious method of obtaining a constant speed has been adopted. The general arrangement of the dynamo and drive is shown in fig. 13, in which A is the carriage axle, which drives the shaft B by means of the belt C. The dynamo is attached to the frame of the coach by the link D, which has pins at E and F, its actual position being determined by the adjusting rod G. It will be noticed that the machine is held out of the position it would naturally fall into, by the belt, and a definite tension is therefore put upon the latter. In running, the tension on the driving and driven portions of the belt will vary, the variation increasing with the speed, and at a point when this difference exceeds the force due to the dynamo being out of

centre, the belt will tend to swing the dynamo still nearer to the carriage axle, causing the belt to slip on the small pulley on the dynamo shaft. The result is that, whatever the speed of the axle may be above a certain point, the speed of the dynamo shaft to which the armature is attached will remain constant, and therefore the current developed will remain the same. The screw G allows of the position of the dynamo being altered within considerable limits, and in this way the initial tension on the belt and maximum speed of the armature may be governed.

The dynamo switch and governor do not occupy a great deal of room under a coach, the overall length of the casing being about 3 ft. The

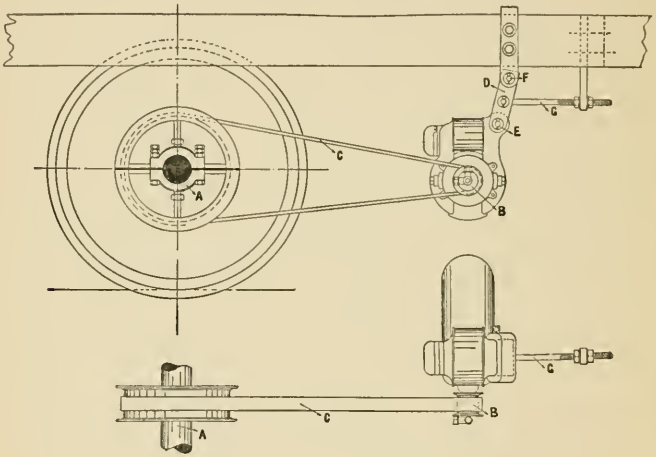


Fig. 13.—Arrangement of Stone's Dynamo showing Drive

general arrangement of parts is shown clearly in fig. 14, which is a section through the casing, and shows the armature at A with the magnet B on the top, whilst the commutator and carbon brushes are fixed at C. It will be noticed that special steps are taken to prevent the dust entering the casing at the only point where a fixed joint cannot be made, namely, where the shaft enters near the driving pulley. This is a very necessary precaution where a machine has to run in such dust as is often found under a railway coach. To the left of the commutator lies the automatic switchboard D, which contains the various contacts which are made by the rocking arm E. This arm is capable of rotating about 90 degrees relative to the fixed switchboard, whilst it is connected to the governor so that it may be forced along the shaft from left to right as the pressure rises. The governor F consists of two weights on short arms, which, as they fly out, press the framework G to the right. On this framework are fixed two plungers H,

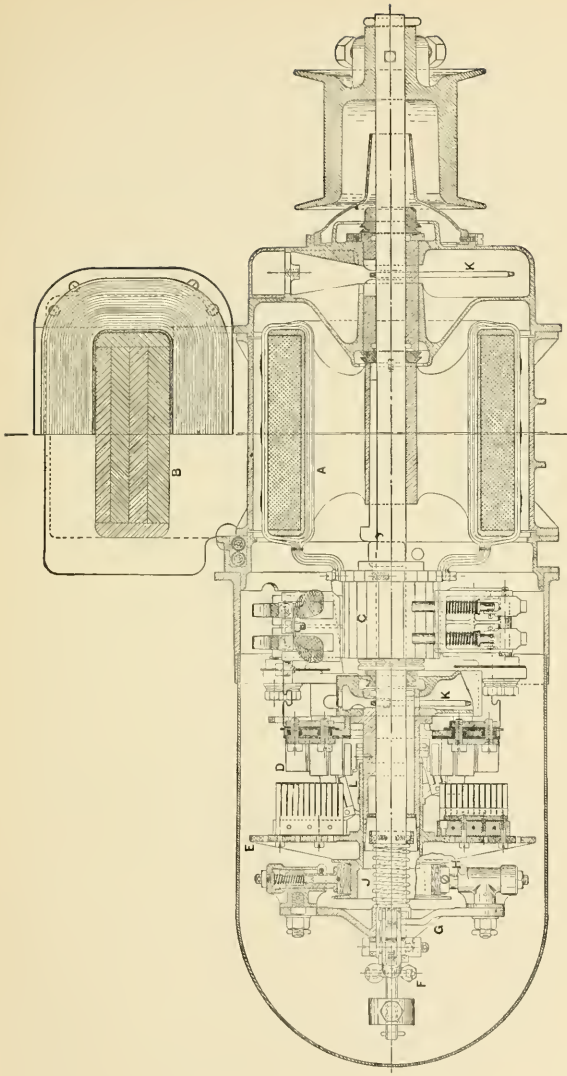


Fig. 14.—Stone's Dynamo for Railway-carriage Lighting

terminating in wooden blocks which run in a flat-bottomed groove attached to the rocking arm. These plungers run free from the bottom of the groove at full speed; but at low speeds they are held down on to the bottom of the groove by springs, with sufficient pressure to enable them to carry the rocking arm through the necessary angle when the direction of rotation is reversed.

As the speed of the shaft increases, the centrifugal governor forces the rocking arm forward. This closes a switch connecting the magnet coil to the battery, changing over also, if necessary, the see-saw switch

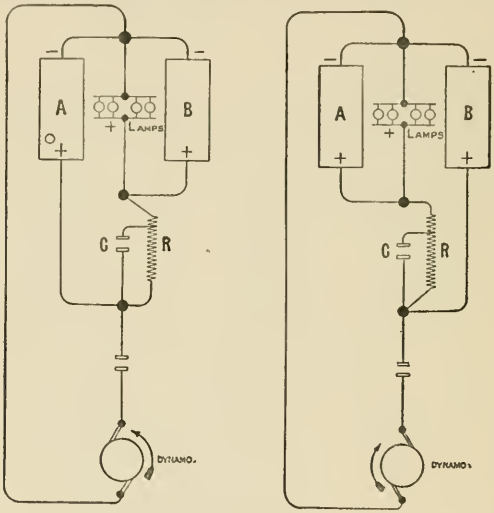


Fig. 15.—Diagram of Batteries, &c. (Stone's System)

and when the dynamo is generating a voltage somewhat higher than that of the battery, closes the main circuit; whilst another short-circuiting switch throws in the necessary resistances. As the coach slows down the action is reversed, a strong spring J helping to close the governor balls and force E back to the left. In the more recent dynamos ring lubrication, as shown at K on either side of the armature, is employed, and oil throwers on the shaft prevent the oil from getting into the windings and on the commutator.

The two batteries, usually of twelve cells each, are arranged in parallel, with a resistance interposed on the positive side, so that one receives a charge if more current is made than the lamps require, whilst the other regulates the voltage at the lamps. The arrangement is shown in diagrammatic form by fig. 15, in which the two batteries are shown at A and B.

When standing, each of them helps to supply the lamps, but it will be seen that current from B has to pass through part of the resistance R, and therefore the greater current is supplied by A, assuming that the batteries are in an equal state of charge. When the coach commences to move and the rocking arm has been pushed in, current is supplied direct through the switch C to the lamps, battery A providing the remainder. As the speed increases, the short-circuiting switch C opens and the current from the dynamo divides, and part passes through the resistance to the lamps, whilst part charges B. As still greater current is generated, less requires to be discharged from A, and finally all that the lamps require is supplied from the dynamo, the excess flowing through, and charging B. When the coach runs in the reverse direction B becomes the regulating battery and A the one receiving a charge, the connections being changed by the see-saw lever and the rocking arm. When long daylight runs are anticipated and no lamps are required, a switch is sometimes arranged so that the resistance is cut out and each battery receives an equal charge, as otherwise the regulating battery receives the current.

The above is a description of the general system adopted by Messrs. Stone, but it has of recent years been subjected to several important improvements in detail. A single battery is sometimes used where the lighting requirements are small, and where close regulation of the voltage is not the most important consideration, as with horse-boxes, brake vans, &c. The double-battery equipment is, however, undoubtedly preferable and is more generally employed.

The principal modifications which are embodied in the "Lilliput" equipment are that the change of polarity is effected by rocking the brushes through a predetermined angle in place of the centrifugally operated switch, whilst the automatic connection and disconnection of the dynamo and batteries is carried out by means of a magnetic switch separate from the dynamo and carried in a cast-iron box usually attached to the underframe. The dynamo is provided with ball-bearings carried in housings, which enable the armature to be easily removed without disturbing other parts of the machine.

As the name implies, the machine generally is smaller and lighter, and can therefore be handled and housed under the underframe easier, whilst the reduced clearances, reduction in air gap, and other modifications in electrical design have made for increased efficiency.

Instead of the batteries being changed over when the direction of running is changed, as was the case in the system described above, on the new system an electrically operated switch changes over the batteries every time the train restarts after a stop, thus ensuring the best conditions for the battery.

These systems, which are manufactured by Messrs. J. Stone & Co., of Deptford, London, have an extended use throughout the world.

Electrically Controlled Voltage Systems: The "Vickers" Single-battery System.—The Vickers system, which is used on several

British railways, varies materially from the system which was known as the Vickers-Hall.

The dynamo, which, as in other cases, is driven by a belt from the carriage axle, is a direct-current shunt-wound machine, and its weight together with a spring maintains the necessary tension on the belt. The machine is of very simple construction, and the only mechanism attached to the dynamo proper is that necessary to ensure that the current for charging the battery shall always flow in the same direction. This is ensured by arranging for the polarity of the external circuits from the dynamo to remain constant in whatever direction the armature rotates. A brush rocker with four brushes to equalize the strains is provided, and this may be carried by the friction of the brushes on the commutator through rather more than 90° with the armature when the direction is reversed, the actual movement being regulated by adjustable stops which allow of a suitable amount of lead being given.

The mechanism for dynamo regulation is mounted on a separate panel, which, besides fuses for protecting the main current and the various shunts, contains:

1. The field regulator.
2. The field regulator solenoid.
3. The cut-out.
4. The adjustable shunt or diverter for setting the dynamo output and lamp load.
5. The cell protector.

The *field regulator* consists of a number of high-resistance grids connected to two parallel groups of contacts, on which a brush is rocked by the action of the *regulator solenoid*. The plunger of this solenoid is connected to the curved brush, which it rocks on the contacts, so cutting in-and-out resistance in the field circuit; this resistance is all cut out when the brush is at the bottom, and all in when at the top of its travel. The solenoid is compound wound, the main current from the dynamo to the battery being connected in series with the main winding; the current carried by this winding is practically constant in amount above a certain limited speed, as any excess causes the plunger to rise, so inserting resistance in the shunt winding, or the reverse in the case of a drop in current. The other winding on the solenoid is of fine wire, and is inoperative until it is cut in by the cell protector. It is then acting in the same direction as the main winding, and so increases the resistance in the dynamo field and prevents the battery from being overcharged. The dynamo cut-out is arranged to automatically close or open the circuit to the battery and lamps at a predetermined voltage, being operated by a compound electromagnet, the shunt coil of which is across the dynamo terminal and the series in the main dynamo circuit. The *adjustable shunt or diverter* is a resistance arranged so that any desired amount of it can be connected in parallel with the main coil of the regulator, so regulating the dynamo output. The *cell protector* is a cut-out switch similar to the dynamo cut-out. The magnet is shunt wound and connected

across the dynamo mains, and the air gap between it and the armature can be varied so that the switch will operate at a predetermined voltage.

In the circuit there is a lamp voltage regulator which is similar to that of the dynamo field regulator, but the solenoid has only one winding which is connected in shunt across the lamp circuit.

Fig. 16 shows a diagram of the connections of this system with the

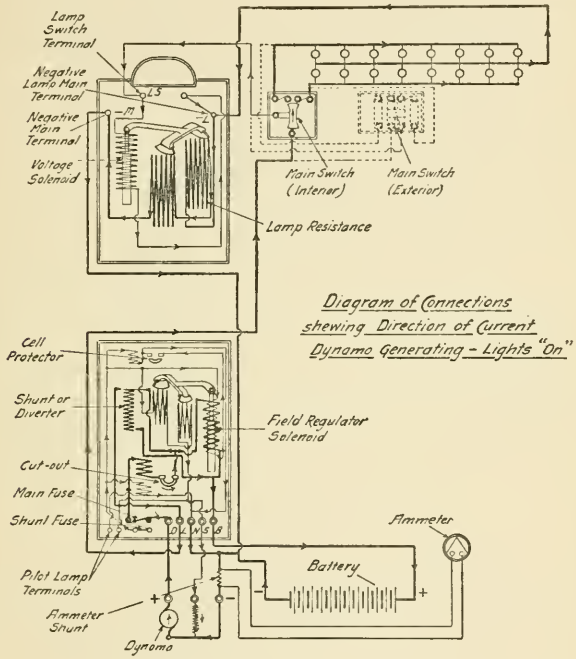


Fig. 16.—Vickers Single-battery System

direction of the current, and with the above description the operation will be easily followed.

It will be seen that it is a single-battery system. It is manufactured by Messrs. Vickers, Ltd., London, and is in use on a number of British railways.

Leitner-Lucas System.—The Leitner-Lucas system of lighting consists primarily of a dynamo, battery, and automatic cut-out, the connections being shown diagrammatically on fig. 17. Only one battery is employed, and the regulation of the voltage is arranged electrically. When the system was first brought out this was arranged for by means of a separate small

" demagnetizing " dynamo on the same shaft as the main dynamo, which weakened the field as the speed increased. This has now been superseded by an extra pair of brushes, D, D_1 on fig. 17, which takes its place, acting in the same manner. Upon starting, current flows from D to D_1, and assists in building up the field rapidly, but as the armature current increases, the field flux is distorted, and the voltage between D_1 and D is gradually reduced to nothing, and finally D_1 becomes negative and D positive. Further increase in current makes the voltage between D and D_1 rise, causing the shunt current to be decreased and the main voltage to be kept constant at about 26 volts. An auxiliary field coil G is also employed, it being in series with the lamps

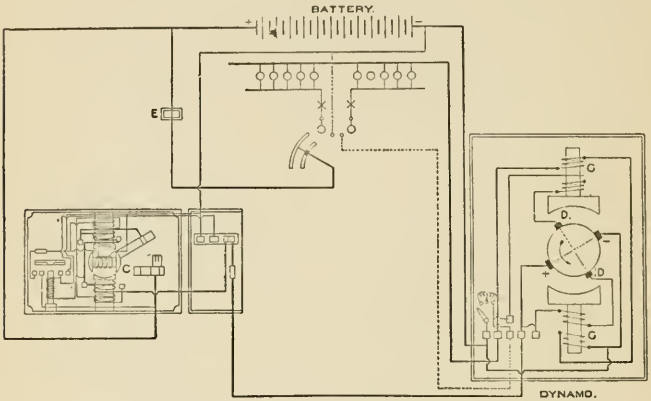


Fig. 17.—Leitner-Lucas System: Diagram of Wiring

and assisting the dynamo field winding. The automatic cut-in and cut-out switch is shown at C, and is arranged so that the batteries are cut in or out as the dynamo voltage falls below or rises above that given by them. This is not dependent upon any particular speed or voltage, but takes place whenever there is a difference between them. This system has no pole-changing switch, but the brushes on the commutator are rotated 180 degrees electrically.

The regulation of the current to the lamps themselves is provided for, either by means of a regulator, which, when employed, is inserted in the circuit at E, or by lamp resistances, which are placed at X. The former of these (a detailed description of which, with the rest of the system, may be found in *Engineering*, 16th February, 1906) provides for the automatic governing of the current by means of throwing in or out resistances, the contact arm being actuated by a small series-wound motor. A number of coaches on one English railway are lighted by this apparatus, which is made by Messrs. G. D. Peters, of London.

Train Lighting: Dalziel's Constant-voltage System.—This system aims at attaining a constant-voltage dynamo regulating independently of the battery, hence the term "constant-voltage", distinguishing the system from battery-regulated constant-current types

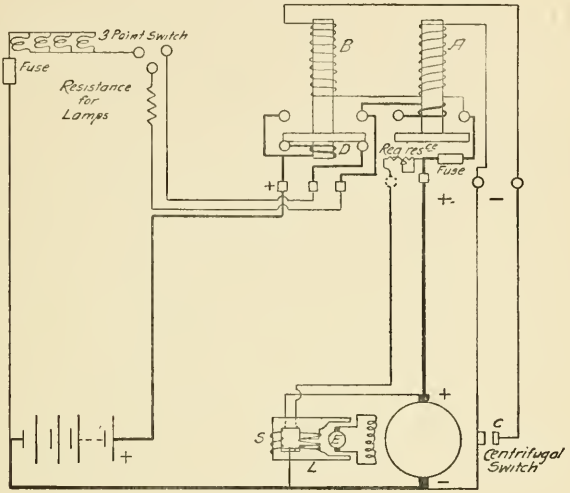


Diagram 1

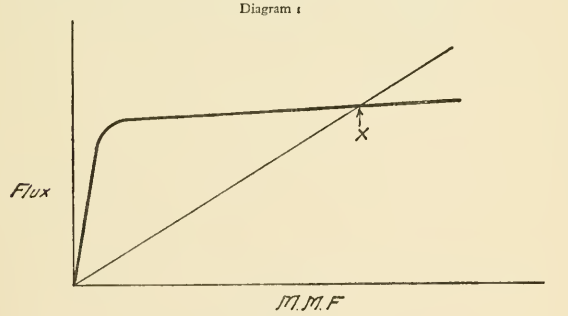


Diagram 2

Fig. 18.—Dalziel Constant-voltage System

The system works at 2·35 to 2·5 volts per cell. The battery is its own overcharge preventer, its rise of back-E.M.F. cutting down the input to it. Output depends solely on requirements and may be zero. The battery takes no part in the regulation, and is relieved from wear and tear and

from under- or over-charge damage, and the adjustment of output required with constant-current systems for seasonal or trip variations in lighting is eliminated.

For regulation the difference in characteristic of heavily-saturated and under-saturated fields is utilized. Originally the two fields were provided in separate small parallel-connected motors, but later were combined into one iron circuit, the residual flux of their difference exciting the armature of an exciter, which in turn excites the main machine. Both fields are excited across the main generator terminals. The under-saturated field generally contains an air gap exaggerating the straight-line type of its characteristic.

Diagrams 1 and 2 (fig. 18) illustrate the system. The saturated field S is the main one. As voltage rises, and with it the excitation of the under-saturated field L, the latter increasingly diverts flux from the exciter armature E. As point X (diagram 2) is approached, where the two characteristics cross, further increase of main voltage becomes impossible, as otherwise the flux of L would wipe out that of S and of the exciter and main fields altogether.

Lighting voltage is 2 volts per cell; the excess potential is absorbed in lighting resistance by the switches shown in diagram 1. Diagram 1 shows also the method of switching in and out. The dynamo is switched in at a predetermined voltage by switch A connecting it to the battery through the lamp circuit and resistances. Meanwhile the second switch B has its excitation circuit closed by the centrifugal switch C, but is held down by lighting current from battery in coil D. The dynamo gradually takes over the lights from the battery through their resistances, until, when current ceases in coil D, B switch rises, putting the dynamo directly across the battery with a minimum of flicker. In switching out, switch B is dropped by centrifugal switch C, switch A falling as the voltage drops further.

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